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Computer Solves Vital Operating Problems 16

KEY MEN DISCUSS

Responsibility Accounting from 3 Angles 25

PLANNING AHEAD

How to Deal with Transient Surges 32

IDEAS OF THE FUTURE

New Spray Coating Dampens Vibration 42

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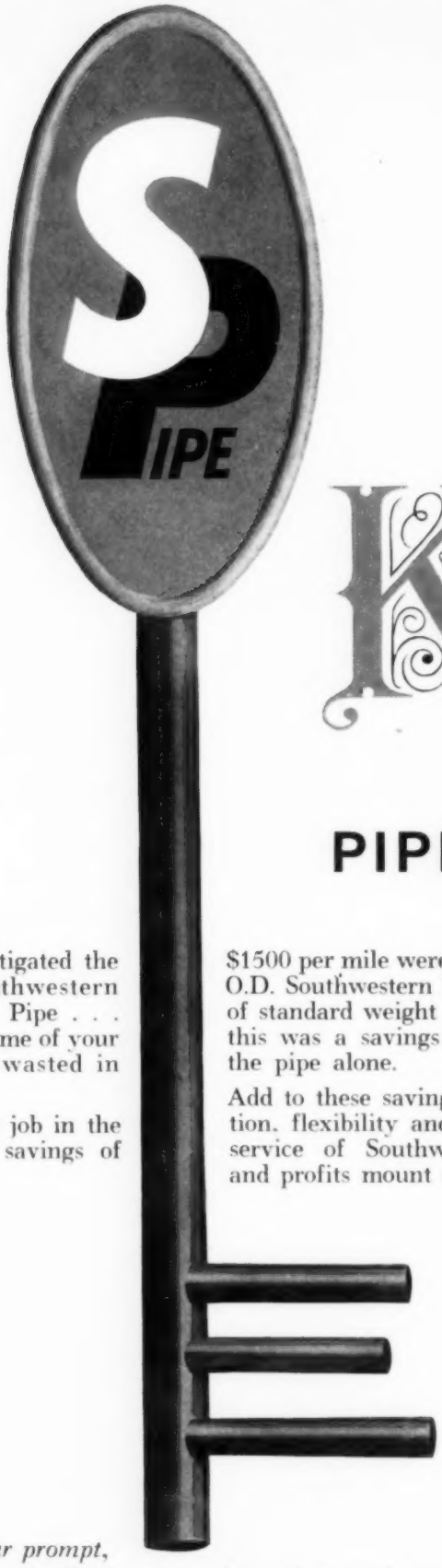

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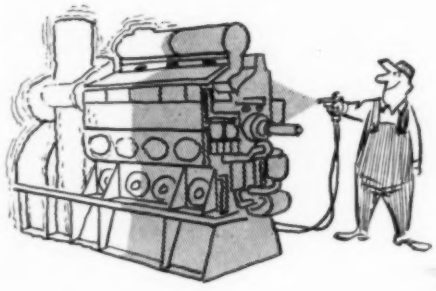
PIPE LINE INDUSTRY

A GULF PUBLISHING COMPANY PUBLICATION

May 1960 Vol. 12, No. 5

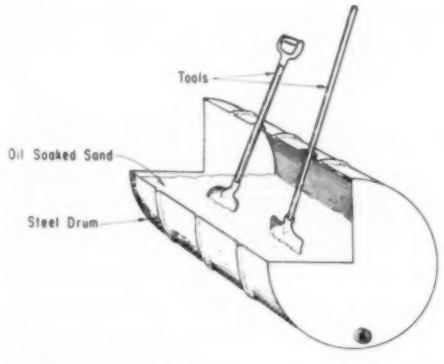
CONTENTS and Quick Look

To help you put first things first, scan these time-saving digests, checking ☑ those you want to read first.



Ideas! Ideas! Ideas!

☐ Spray-on coatings are now being used to dampen machinery vibrations. Vibrations are converted into shearing forces that are dissipated within the coating material. Would this make a good internal coating for discharge piping? Page 42



Take a Hint

☐ An old oil drum and a little sand can be used to make a convenient outdoor tool rack. Read about this and other helpful hints on Page 50

Is Industry a Political Image?

☐ Presidential hopefuls are painting a distorted picture of industry taxation. What they are saying, plus ways to counteract anti-industry political actions, are presented on Page 4

SPECIAL API REPORT

Digital Simulation of Pipe Line Operations

☐ With computers getting faster and easier to program, it is possible to "predict the future" so far as operation of pipe lines is concerned by simulating their operations. The author shows how Shell simulated automatic controls, two-phase flow, operating characteristics of heated oil line, hydraulic profiles and economic factors.

By T. R. Young . . . . . Page 16

API Symposium on "Responsibility Accounting"

☐ Basically, the term "responsibility accounting" means supplying accounting information to those who are directly responsible for the expenditure of the funds. Never has this task been more important than it is today. It can mean the difference between good management and poor, between a prosperous company and one headed for bankruptcy. Here are discussions by three key men in the field.

By W. F. Krick, G. M. Johnson and S. D. Williams . . . . . Page 25

Controlling Transient Surges When 5,000-HP Turbine Drops Off the Line

☐ When the large horsepower package drops off line, there is a pressure wave generated at the suction which travels up stream at considerable velocity. This wave could damage the Tapline 31-inch pipe, so the company had to devise a solution to dampen the wave in certain critical areas. A relief bleed-off set-up was installed at one station. This exerts a dampening effect on the wave. Also, engineers devised a means of generating a rarefaction wave from an upstream station which would meet the pressure wave and cancel it out before it reached the critical piping.

By R. R. Burnett . . . . . Page 32

The Railroad Rhubarb

☐ For years pipeliners and railroaders have tried to agree on the problem of sizing the wall thickness of casing used on under-railroad crossings. The problem has proven a difficult one. An article published in the January issue of PIPE LINE INDUSTRY has prompted an exchange of letters on the subject. Page 8

REGULAR MONTHLY DEPARTMENTS

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PIPE LINE INDUSTRY published every month. Entered as second class mail matter July 9, 1954, at the post office at Houston, Texas. © Gulf Publishing Co., 1960.

Is Industry Becoming a Political Image?

THE SCRAMBLE for presidential and vice presidential votes is underway—and let economic reality take the hindmost.

Political speeches and front page newspaper stories already are laying groundwork that will make a tough job tougher for pipe line companies during the next session of Congress. Headlines blasting pipe lines' "anti-consumer" actions are just one of the many-faceted attacks to come.

Another target is the depletion provision. Hubert Humphrey has called public attention to the need to "eliminate the $5 billion in tax loopholes." Hidden between those seven words is a plan to reduce the depletion provision. Senator Stuart Symington, in a recent press conference, expressed his belief that the depletion percentage should be cut from 27½ to 15 percent. This, of course, follows his previous stands on the issue during 1958 and 1959.

As usual, there is, and will be, a loud silence when it comes to making pledges to reduce government waste, cut back excessive federal control or to ease the excessive gasoline tax that is eating into the pocketbooks of American motorists.

Just as noticeable will be silence regarding ways to ease increased industry labor and equipment costs, tightening profit margins or the need for a higher, not lower depletion percentage. It appears that such pledges are not what the public wants to hear—or are not the kind that produce votes.

Can you imagine one of the political candidates making such public statements as:

"Within the next 40 years population totals will double in the United States. Thus, the oil and gas industry will need every possible incentive to find enough reserves to meet soaring demand."

Or, "In the past seven years the price of finished steel has gone up 37 percent, wages have increased 30 percent, and oil field machinery has increased 26 percent, yet the price of crude has increased less than 10 percent. Ways must be found to ease the cost-price squeeze so the industry will have the incentive needed to continue to find enough reserves to meet our rapidly increasing energy requirements."

Or, "Unless the current depletion provision remains intact, slackened industry operations will quickly cut deep into domestic crude oil reserves. If this occurs, the nation will be at a decided disadvantage. The United States needs the oil. And the 27½ percent depletion provision is a major reason why this country never has had inadequate supplies. This should be reason enough not to upset the apple cart."

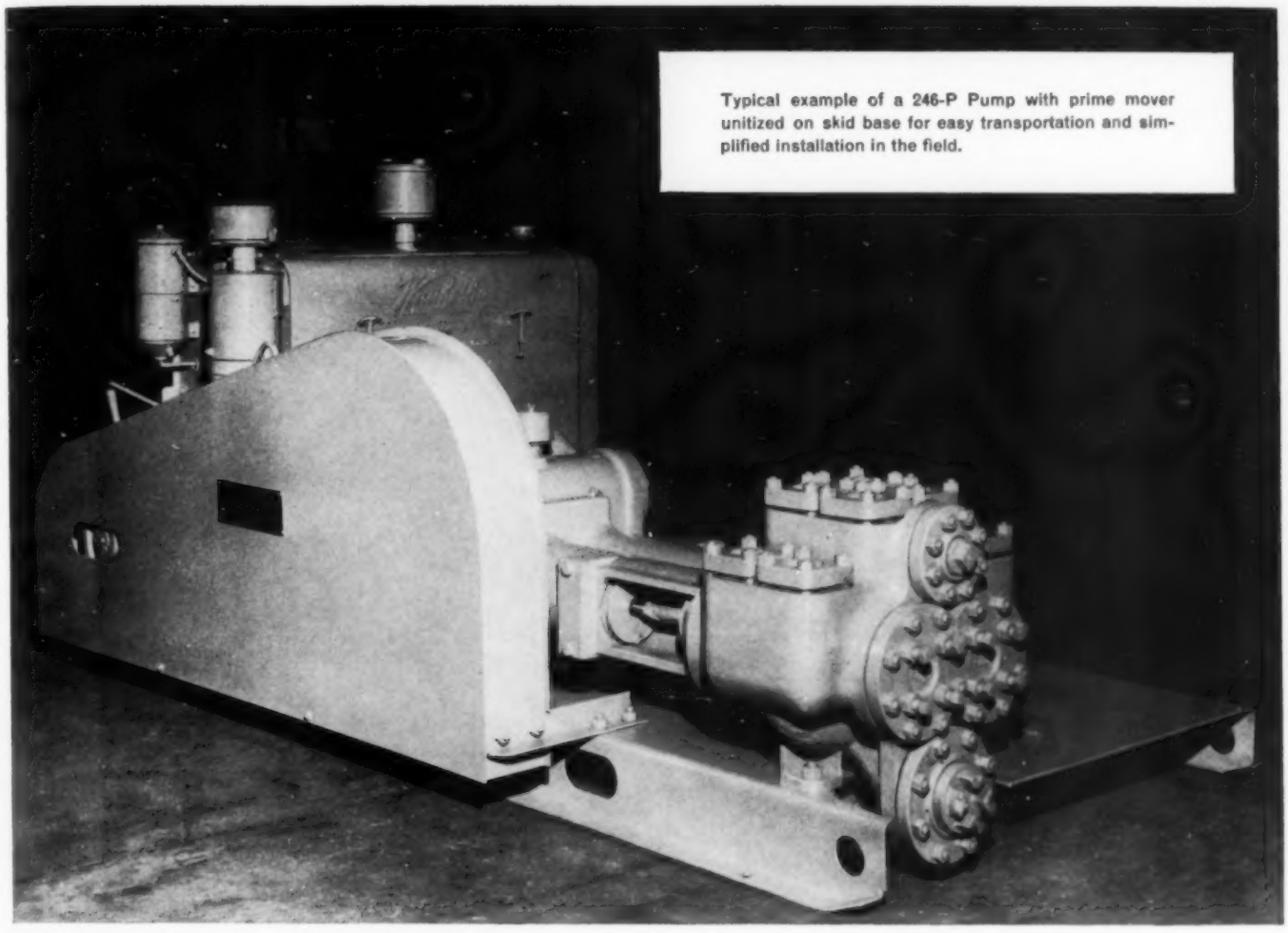
Such realistic economic statements obviously will not be forthcoming during this presidential election year. Yet, they must be presented to the public.

Positive action must be taken to help the public understand that the political image of the pipe line industry is not necessarily the true image. The economic problems, a true profit picture, future demands on pipe lines—all of these must be completely and simply defined.

How can this be done? By more active industry participation in local, state and national politics. By properly informing employes, stockholders and customers. By explaining the tangible benefits that grow out of a successful industry, unhampered by excessive federal control.

This is the year that voluminous politically based economic statements will be scatter-gunned to the American voters. Thus, this is the year that more attention than ever should be given to acquainting the public with the pipe line industry's side of the story.

Then, when the votes have been cast, perhaps the public will have retained industry's image of industry—not the politicians'.



Typical example of a 246-P Pump with prime mover unitized on skid base for easy transportation and simplified installation in the field.

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Model 246-P – 4″ x 6″

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Piston Size Range Inches	Rated Working Pressure (psi)	Barrels per 24 Hours at Pump Speeds (rpm) of:			
		40	60	80	100
2½	900	651	960	1,269	1,612
3	600	942	1,415	1,885	2,360
3½	450	1,310	1,965	2,620	3,275
4	350	1,730	2,590	3,455	4,320
Brake Horsepower Required		11.5	17.1	22.9	28.5

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PETROLEUM REFINER and The REFINERY CATALOG for the oil, gas and petrochemical processing industry.

Indexed by Engineering Index

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SUCCESS DEPENDS ON "TEAMWORK"

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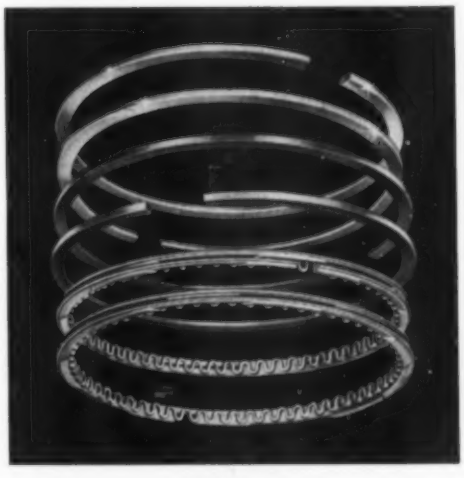

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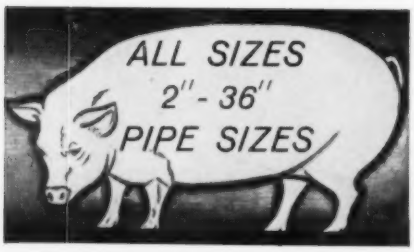
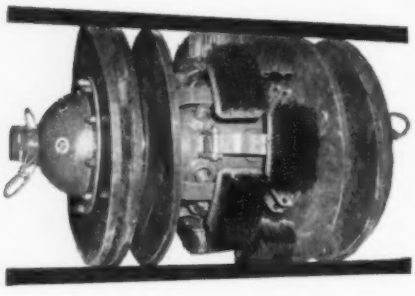
Pedrick PISTON RINGS

PEDRICK PIONEERED *Conformable* RINGS IN ENGINEERED SETS FOR BIG-BORE ENGINES

MYOCO PIPELINE PIGS



ANY COMBINATION ALWAYS IN STOCK



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Letters

Railroad Rhubarb

An item in Pipe Line Panorama (January, Page 17) on specifications for the wall thickness of casing used in underrailroad pipe line crossings and remarks on the same subject in the article "Designing Pipe Line Crossings of Railroad and Highways" by Ernest A. Slade (January, Page 31) have prompted the following comments by representatives of the American Railway Engineering Association on the American Society of Civil Engineers Committee on Pipe Line Crossings Under Railroads and Highways.

To the Editor:

The January 1960 issue of PIPE LINE INDUSTRY contains a news item on Page 17 and an article entitled "Designing Pipe Line Crossings of Railroads and Highways" by Ernest A. Slade, pages 31 to 36 inclusive, portions of which are premature, misleading, and the cause of grave concern to the undersigned. We are former and current representatives of the American Railway Engineering Association on the American Society of Civil Engineers Committee on Pipe Line Crossings under Railroads and Highways.

The news item refers to "recently completed new set of specifications for pipe line and railroad crossings." This is not correct. The Committee appointed by the American Society of Civil Engineers to look into the question of pipe line crossings under railroads and highways has prepared various draft specifications, but none is complete. No one is in a position to state whether or not the "impasse" may be resolved soon.

At an early stage in the proceedings of the Committee, it was agreed that no information in connection with its work would be published until the Committee released or issued formal reports or specifications to the various groups represented. No report or specification has been issued and portions of the article on pages 31 to 36 inclusive are therefore unauthorized. Permission was not requested from the AREA to publish material in connection with its Manual of Recommended Practice dealing with pipe line crossings.

Since what was entrusted to the members in confidence has now become public, the AREA representatives would be justified in disclosing information to refute certain statements and in furnishing data on design calculations and recommended stress levels. We, however, do not propose to jeopardize further the work of the ASCE Committee by exercising this prerogative even though our comments are thereby limited in scope and effectiveness.

The article referred to includes the following paragraph:

"AREA recommended thicknesses could not be determined by use of these equations."

The calculations based on the equations used by AREA to determine its table of casing wall thicknesses can be supplied to Mr. Slade or any other member of the Committee at any time for use as a member of the ASCE Committee, but these calculations cannot be published.

The AREA representatives disagree with the statement on Page 33 that the AREA requirements often result in needless waste of steel. Our views in this connection are well known to members of the ASCE Committee, but cannot be published.

The same sentence contains the phrase *"use of the flexible conduit or Iowa formula . . . now being used by the ASCE Committee for Design Criteria."* This statement is incorrect. The ASCE Committee had not adopted the use of the "flexible conduit or Iowa formula" at the time that the article was published.

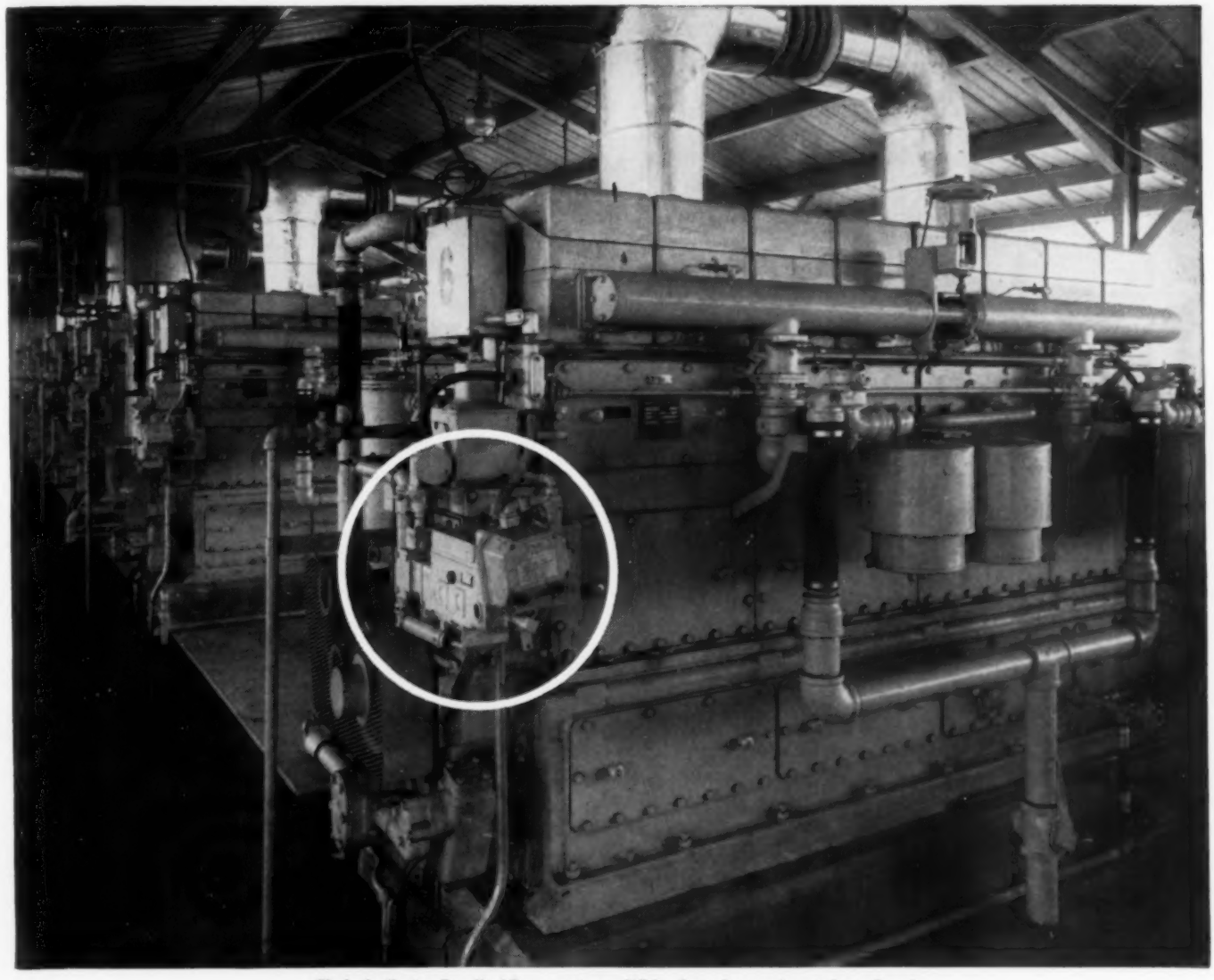
The design limitations summarized in Table 2, Page 36, include certain percentages which were submitted by AREA representatives on a tentative basis pending further consideration. These have been revised and therefore the table is no longer correct.

A portion of the final paragraph reads "the present attitude . . . taken by certain members of the AREA and highway groups is to follow a course of resistance to all change from the presently prescribed AREA specification, or failing that, to make the specifications so drastically limiting that its use would not be adopted by the industry", presumably the pipe line industry. This is incorrect, misleading, and to say the least unkind.

The AREA representatives on the ASCE Committee cannot recall an instance where the highway groups followed a course of resistance to all change in the AREA specifications. To our knowledge the highway representatives have quite properly confined their deliberations to pipe line crossings under highways.

On Page 33 Mr. Slade states that *"practically all railroads now follow the AREA recommendations in their requirements for casing before crossing permits will be issued."* Actually large numbers of crossings have been built to AREA requirements and their use has therefore been adopted by the pipe line industry for those installations. Crossings will be built to these requirements in future and until such time as revised recommendations are adopted by AREA.

The research planned in conjunction with the work of the ASCE Committee



Circle indicates Bendix LC magneto on White Superior engine at Long Beach.

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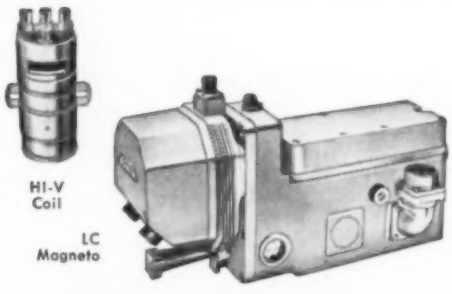

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TRANSCONTINENTAL Gas Pipe Line Corporation

Letters

will be of benefit if all groups approach the problem objectively. To do this it must be accepted that the information to be secured cannot be confined to the parameters or concepts of existing design methods. The possibility of a new design criterion must be recognized.

A. J. Wegmann,
Representing AREA Committee 1

J. W. Purdy,
Representing AREA Committee 1

K. W. Schoeneberg,
Representing AREA Committee 1

C. A. Roberts,
Representing AREA Committee 15

C. Neufeld, former Representative of AREA Committee 15.

•

Following is Mr. Slade's reply to the above letter:

To the Editor:

The article "Designing Pipeline Crossings of Railroads and Highways," appearing on pages 31-36 inclusive of the January 1960 issue of PIPE LINE INDUSTRY, contained certain portions of the then proposed ASCE Design Criteria. I take responsibility for the release of this information without prior approval of the ASCE Committee and wish to retract all portions of the article relating to the Design Criteria of the American Society of Civil Engineers. I wish to express my apologies to the ASCE Committee membership for having discussed these criteria before they were in final form.

I have been furnished a copy of the letter to you from the AREA members of the ASCE Committee, and I cannot completely agree with all of the statements made therein. For example, I was unable to compute the AREA recommended thicknesses by use of the Talbot equation shown, at the time the article was written last September. During the February 1960 meeting of the ASCE Design Task Group, the equation was discussed, and at that time the AREA representatives advised of certain assumptions that had to be made. This information was not presented previously when the AREA members were requested to show the committee how casing thicknesses were determined for inclusion in the AREA manual.

The question of whether following AREA results in waste of steel by pipe line companies is, of course, controversial. When compared to API Code 1102 recommendations and the proposed form of the Iowa Formula being considered by ASCE, there is a definite difference in wall thickness of casing required. For example, in 24-inch casing API recommends .281" wall 71.25#/ft., AREA requires .375" wall 94.62#/ft. and the ASCE formula allowed .219" wall 47.61

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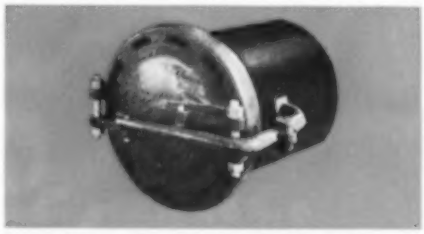
The Unibolt Hinged Blowdown, or blowoff head, is an ideal companion to the Unibolt Scraper Trap on gas line service.

Complete details are carried in Bulletin PL-590, copies of which will gladly be sent on request.



A hinged type Unibolt Scraper Trap in closed position.

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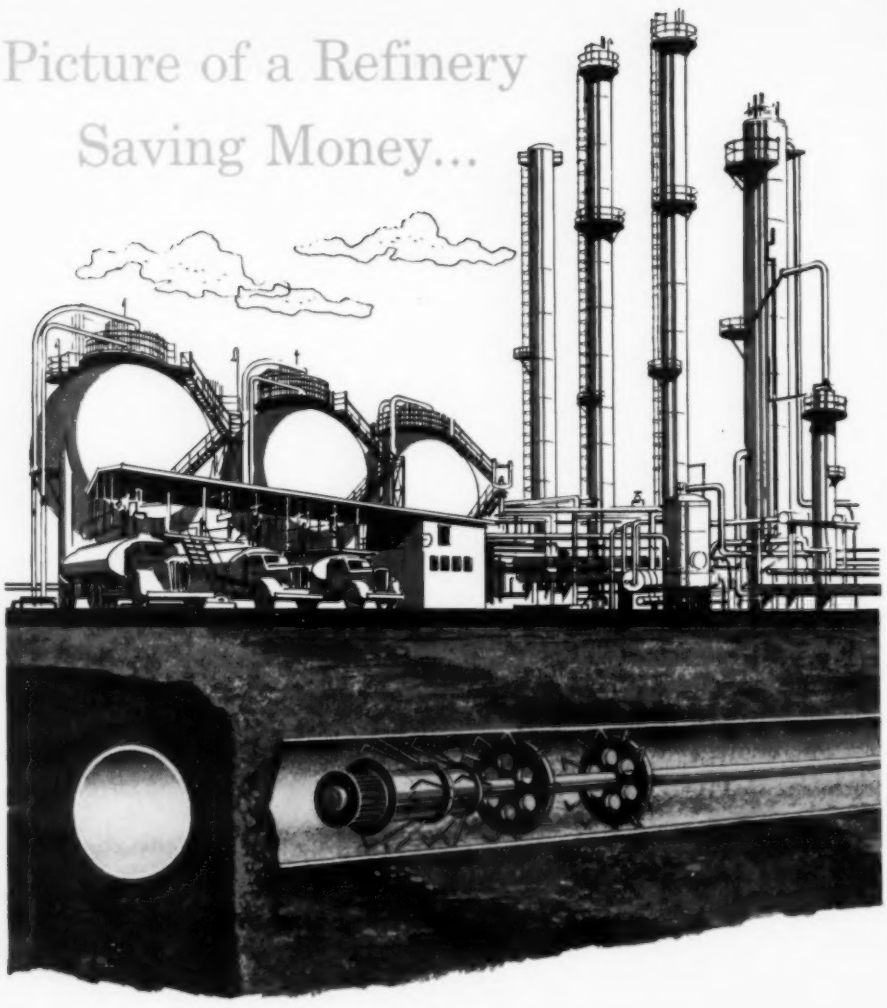

Spunline Relines Pipe Lines in-place without removing the pipe

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Letters

#/ft. These values show a saving in steel of 23.37#/ft. or 25% in favor of API over AREA, and 47.01#/ft. or 49% in favor of ASCE over AREA. Using an average cost of $200 per ton or 10c per pound for steel pipe at the job site, it is obvious that considerable savings in both steel and dollars can be made in a year's time when all pipe line crossing construction in the oil and gas industries is considered.

The statement that "practically all railroads now follow AREA recommendations in their requirements for casing before crossing permits will be issued" is still true, and the fact that large numbers of crossings have been built to AREA requirements by the pipe line industry does not necessarily signify that such standards have been willingly adopted by the pipe lines. In fact, the adoption of these standards has been the only means, short of condemnation proceedings, of obtaining a permit to cross certain railroads.

It is sincerely hoped that the work of the ASCE Committee can go forward rapidly because the problems of crossing design are of paramount importance to the pipe line industry.

The interstate highway system now under construction, using funds derived primarily from the taxation of highway users, will require the installation of a tremendous number of new and relocated cased pipe line crossings. This has placed a great burden on the pipe line industry and highway engineers to search for and utilize the most economical and sound engineering design to best serve the public interest.

Ernest A. Slade
President, Okan Pipe Line Company

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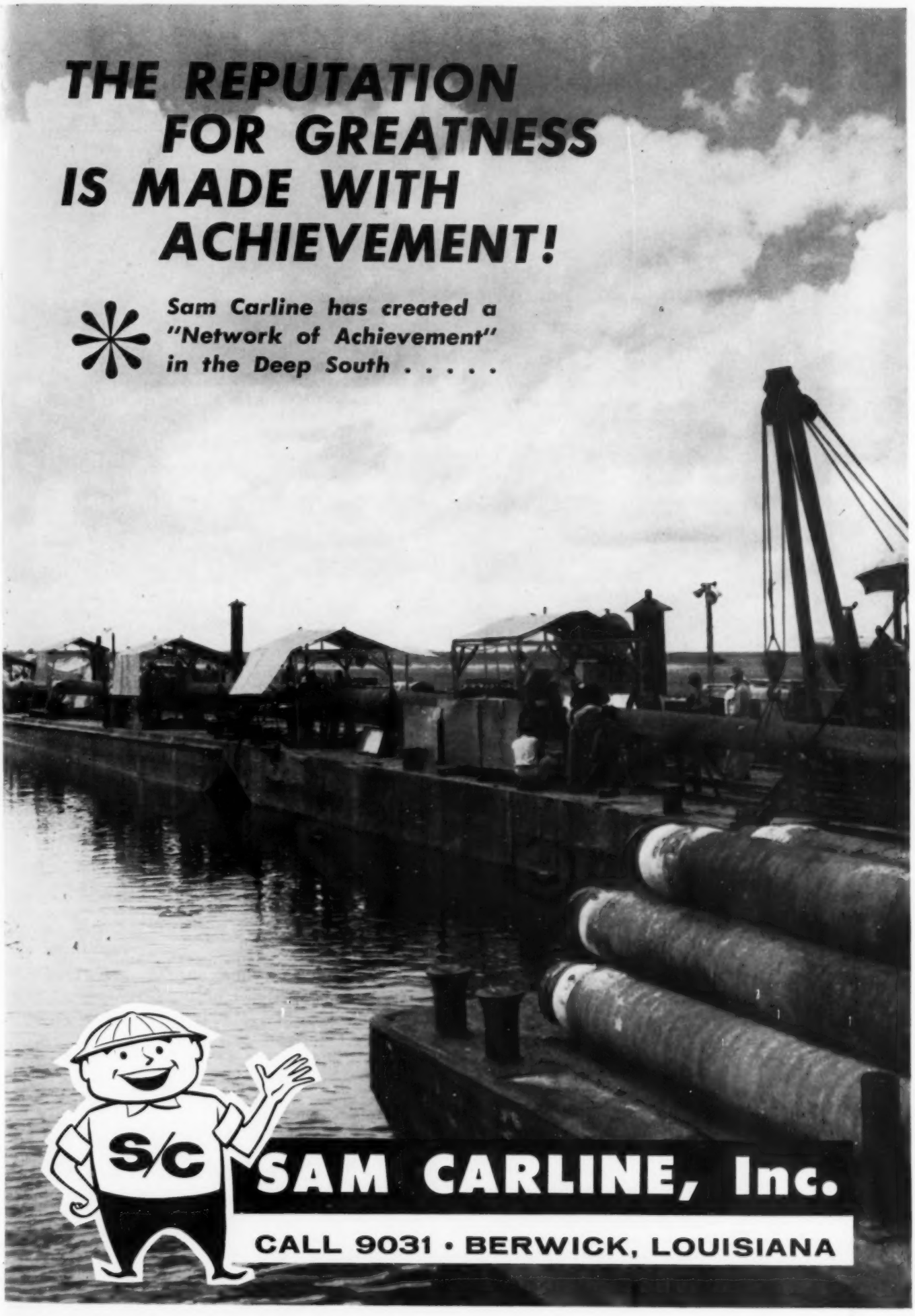
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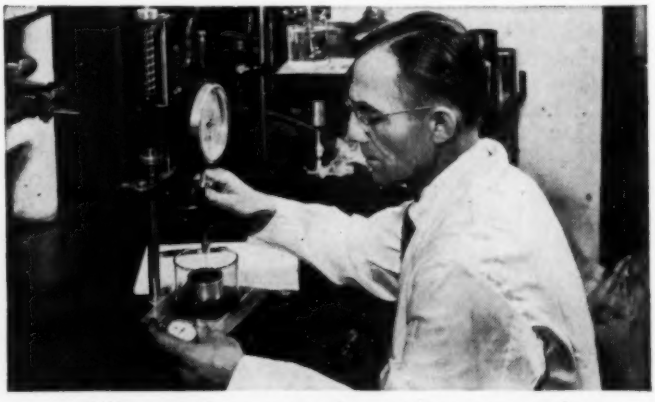
1 *During the next ten years, how much money will be invested in new domestic transmission facilities?*
(a) $3 billion; (b) $6 billion; (c) $16 billion.

2 *The cost of coal tar pipeline enamel amounts to what percentage of a pipeline's total cost?*
(a) 1½%; (b) 2½%; (c) 4%.

3 *This coal tar-protected pipeline, buried in salt water laden soil, was found in perfect condition after:*
(a) 12 years; (b) 17 years; (c) 23 years of service.



4 *What coal tar enamel manufacturer produces every drum of its pipeline enamel to written specifications?*

ANSWERS

1 Sixteen billion dollars! This investment is worth the finest protection available.

2 Only one and one-half percent! So why gamble on "economy type" enamels or unproven protective methods when you can have the *proven long-time protection* of coal tar coatings.

3 Twenty-three years! No other popular type of pipeline enamel can begin to match the ability of coal tar enamel to resist moisture absorption.

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PIPE LINE PANORAMA

Shell Pipe Line Controls Pumping Station Without Communications . . . Successfully field tested for five months, Shell's new type controller permits complete automatic control of pipe line pumping station sans communications. Device requires smaller capital outlay than conventional automatic pipe line methods, yet performs most of their functions—including maintenance of pumping station power at the most economical level for handling any predetermined volume of liquids.

Canadian Construction Boom Gets New Impetus . . . Government green light to export upwards of 1 billion cubic feet of Canadian gas per day to the United States has touched off another major pipe line construction program.

Projects Include: Alberta Gas Trunk Line Company's $121.8 million main line through southern Canada's foothills—Trans-Canada's $37.2 million line from Winnipeg area to U.S. border—Alberta Natural Gas' $36.4 million line from Coleman, Alberta to Kingsgate, British Columbia, on U.S. Border. These projects alone will total $195 million, and there will be more to come.

Helium Extraction Plants on Natural Gas Lines? . . . Legislation that would permit construction of up to 12 helium extraction plants on natural gas lines has been approved by House Interior Committee. Private companies would finance and operate plants.

Construction cost (to be borrowed from U.S. Treasury), including interest: $470 million. Government would pay $40 per Mcf for the helium, about double present price, which would allow program to pay out within 25 years.

Pipe Line Briefs . . . Agreement has been reached covering welders' wage rates for next two years. Journeyman wages went up 15 cents on May 1, and will be raised same amount May 1, 1961; welder helpers or apprentices rates remain 15 cents above negotiated common labor rate; however, minimum apprentice rate increased 5 cents May 1, and will go up another 5 cents May 1, 1961—**Need information on Workmen's Compensation laws throughout the United States?** Booklet containing benefits payable in each state, differences in various state laws and general history of Workmen's compensation can be purchased for $1 from U.S. Chamber of Commerce, Washington, D.C.—**Look for stepped up government investigations of pipe line industry.** Representative Ken Hechler (Dem., W. Va.), proposes to introduce bill that would set up "sweeping" Congressional investigation of FPC because of its failure to "protect the public interest in the face of rising natural gas rates". He also has introduced bill which limits practice of granting temporary interim rate increases. Representative Oren T. Harris (Dem.-Ark.) plans intensified investigation of natural gas pipe line activities related to FPC. Probe will start sooner than previously planned, after publicity that resulted from Midwestern Gas Transmission case.

Pipe Line to Link Communist Bloc with Western Europe? . . . Russia has asked that special United Nations committee be set up to study possibility for all-European crude pipe line network. Belief is that Russia wants to tie Western Europe in with crude oil line linking Russia, East Germany, Czechoslovakia, Poland and Hungary.

AN API FEATURE

Digital Simulation of Pipe

How digital computers can be used to simulate automatic controls, two-phase flow, operating control of a heated oil line, hydraulic profiles and economic factors

By T. R. Young
Shell Pipe Line Corporation, Houston

THIS YEAR marks the beginning of the second generation of stored program computing equipment. In many installations, the medium sized computer will shortly be replaced by larger and faster equipment or will be augmented by accessories to increase memory and speed of existing equipment. In a typical installation, monthly computer rentals may increase from $6000 to $30,000 or so under such a modernization program.

If these programs are to be successful, management must participate in their planning and execution. Management must support training of technical staff in the new methods for solving problems, such as modern applied mathematics. In addition, the crossing of department lines should be facilitated in the problem solving process, as the new computing equipment is intrinsically designed for this purpose. Examples pointing up the wide latitude and scope of the new methods of analysis is found in the references.

The computer applications described below cover simulation of crude oil pipe lines in the fields of design, operation, and economics. They represent improvement in engineering practice in several ways: (a) solution of problems not possible by traditional methods, (b) increased accuracy of analysis through the elimination of simplifying assumptions characteristic of traditional practice, and (c) reduction of professional technical labor required.

Automatic control simulation

The Ozark Pipe Line System operated by Shell Pipe Line Corporation consisted of a 10 station trunkline with five remotely controlled stations and five manned stations in 1959. The two types are in alternating sequence. It was desired to further automate this system and, because of dispatcher overload, a ½ percent communication outage and false signal experience in the existing remote control system, an alternative control system was con-

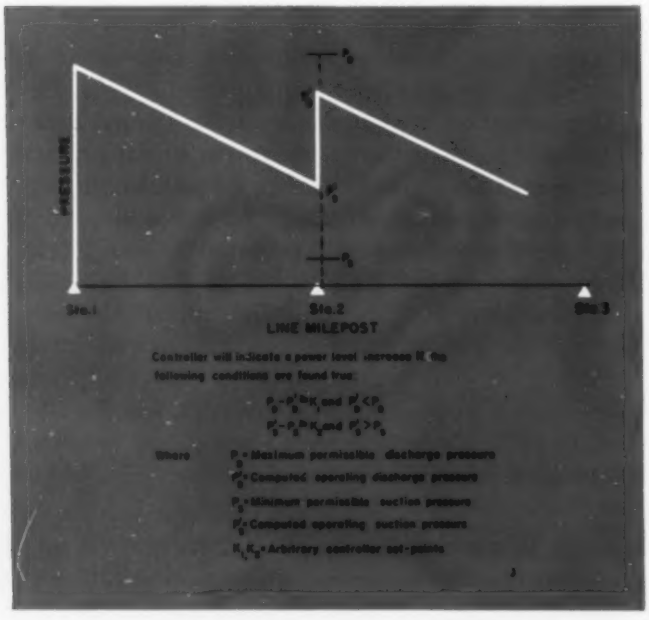

FIGURE 1—A schematic illustration of controller logic for power incrementation, plotted in connection with studies of local power level controller.

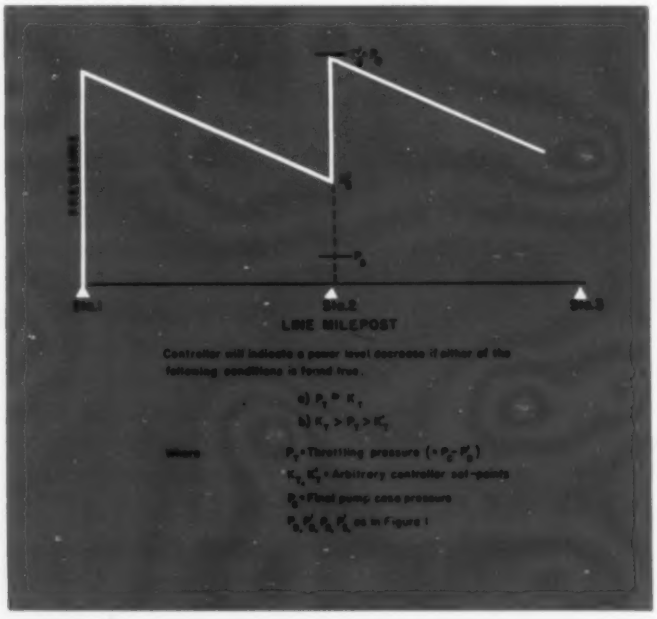

FIGURE 2—A schematic illustration of the controller logic for power decrementation when the station is throttling on discharge.

Line Operations

ceived. The new system was designated a *power level controller*—and has the distinguishing characteristic of fully automatic local station control requiring no communication with a central control point.

Problem. Because of the novelty of the *power level control* concept, it was necessary to secure assurance before installation that the system would be fully operable and free of major fault.

In order to secure this assurance, a computer simulation was developed for the action of the proposed control system in conjunction with the pipe line system. Initial data was obtained using an analog simulation. The analog representation did not give information on the sequence of operations under power level control, and the digital simulation was made to determine this. In particular, it was necessary to determine controller set-point values which would assure freedom from oscillation of control action.

Power Levels. The Ozark System is a 438-mile, 22-inch diameter line with current thruput of approximately 270,000 barrels a day. The 10 stations are each equipped with four pump units of approximate relative sizes ½, 1, 1, 1, giving the opportunity for stepped pressure incrementation as all units are fixed speed drive. The stepped combinations of pumping units are ½, 1, 1½, 2, 2½, 3, 3½, and these are called "power levels." Consequently, "increasing the power level" at a station means adding pressure boost by bringing a half unit on the line or dropping a half unit and adding a full unit. Line rate adjustment is made by a combination of pressure stepping as indicated above and station throttling.

Computer simulation was directed at line start-up and recovery from line upset due to forced pump unit or station shutdown. For both situations it was desired to know that the local automatic control action would lead directly, without hunting, to a stable operating condition for all stations.

Simulation. For the simulation of line start-up the following operations are performed by the computer:

Step 1: Maximum power level to be permitted at each station is read into the computer along with a starting operating presssure for the initial station on the line.

Step 2: The pressure boost at the first station initiates line flow at a rate determined by the first station pressure boost and its attenuation by line friction, station loss, and static head effects. The determination of this rate requires a trial and error solution based on the relation between required pressure boost and pressure developed by active pumping units.

Step 3: Resultant suction and discharge pressures at each station are then determined by direct computation.

Step 4: For those stations at which computed suction and discharge pressures are not within specified limits, station throttling is incremented by an amount proportional to the amount of suction or discharge pressure lying beyond operating limits.

Step 5: The line is then rebalanced as in Step 2, e.g., a line rate is determined, by trial and error, that generates a line friction loss just able to dissipate fully the generated pressure boost from active pumping units. The throttling incrementation (or decrementation) is repeated as in Steps 2-4 until all station suction and discharge pressures have been brought within specified operating limits.

Step 6: Each station is then examined for possible reduction or increase in power level according to controller logic, after which the above sequence is resumed.

The above detailed action of the control system on the line stations is pursued until all stations have reached preset maximum power levels. This completes the simulation of line start-up.

Recovery From Line Upset. The principal additional test of the power level control action was for recovery from line upset. The test was accomplished in the computer program by line start-up modified to simulate forced shutdown. Following start-up, new input data are read by the computer. The new data, in effect, cause shutdown of one or more selected stations by forcing their power levels to zero.

Following forced shutdown, the normal power level incrementation/decrementation process of Steps 2-6 above is executed until stable line operation is secured. The efficiency of line recovery after a simulated station shutdown can be found by observing the pattern of power level adjustment and throttling action. If direct, non-cycling throttling and power level adjustment lead promptly to stable line operation—control action may be considered acceptable.

The exact behavior of the control system and the accompanying hydraulic conditions in the pipe line are reported by the computer at each significant step in bringing the line up. This intermediate data printout occurs at each power level change. Any tendency for overcontrol, hunting, or other unstable control behavior can be detected easily.

The practical use of the simulation program consisted

in the trial use of alternative ideas for controller logic to govern power level incrementation and decrementation. After a satisfactory set of rules for control logic had been found, the simulation work was completed by the determination of values for the controller set points represented by the constants K_1, K_2, and K_T in Figures 1 and 2.

The resulting power level controller design was built as a prototype, installed in the Grand Lake Station of the Ozark Pipe Line System, and performed as predicted. Extensive operational testing of the system, including forced adjacent station shutdown, failed to develop malfunction in the power level control operation.

Two-phase flow simulation

The simultaneous flow of gas and liquid in a pipe line as separated phases has never been subjected to an analysis leading to a practical and reliable design procedure. The basic objective is the prediction of line pressure drop when gas and liquid rates are specified.

The problem is of importance in the case of wet gas transmission lines in which condensate may separate; in crude oil lines carrying free gas as an extra service; and in some process transfer lines in which flashing vapor produces a substantial gas phase.

Complexity of the Problem. The problem has attracted numerous investigators who have proposed a variety of flow correlations, all attempting to predict two-phase flow pressure drop from given liquid and gas rates and suitable physical property information. The complexity of the problem may be appreciated when it is realized that two-phase gas and liquid flow may occur in any of seven different types—*dispersed, wave, annular, stratified, plug, slug,* and *froth*. These flow types have been identified experimentally and approximate agreement exists among most investigators on the nomenclature given above, but the development of a satisfactory design procedure has been impeded in past years by the time consuming calculations required for the estimation of even a single two-phase flow pressure drop.

It has become clear that successful research directed toward the development of a sound two-phase flow design procedure will necessarily employ automatic computation. This makes it possible to compare any given design correlation prediction against a large body of diversified experimental data. It is expected that only such massive computation will permit ultimate confirmation of some future correlation as adequate for general design purposes.

The computer simulation of the two-phase flow phenomenon for design purposes discussed below is based on the correlation of Baker. (See References.)

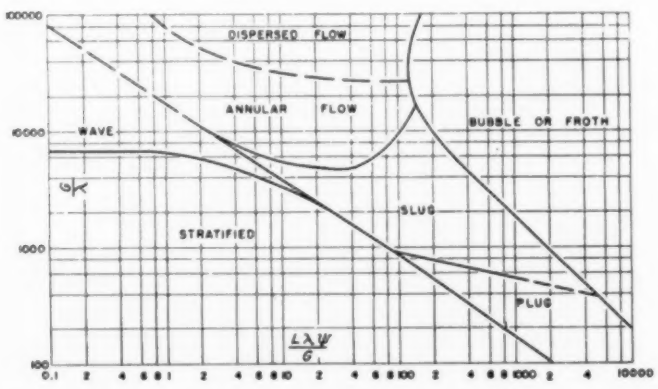

FIGURE 3—Flow pattern regions. Baker (see References) developed this correlation for the seven different types of flow.

Problems involved in the computation include the line pressure drop (to be determined) which itself determines the amount of gas dissolved in the liquid phase, hence the gas/liquid ratio. In addition, the amount of dissolved gas determines the physical properties of the liquid phase, viscosity, density, and surface tension. All of these pressure dependent factors are used themselves for the determination of the internal line pressure, thus forcing a trial-and-error solution.

The problem is further complicated by the known possibility of several types of flow, most of which have been correlated by different empirical equations. Baker has met the problem by developing a flow type correlation shown in Figure 3.

In use, the correlation parameters $L\lambda\psi/G$ and G/λ are computed based on liquid and gas flow rates and physical properties. The pair of coordinates thus found then locate a point in one of the flow type regions of the correlation graph, Figure 3. With the flow type identified, the selection of the associated pressure drop equation is possible and the latter used for the calculation of two-phase pressure drop.

The computation sequence can be described briefly as follows:

Step 1: Read input data describing the line, gas and liquid rates, and physical properties.

Step 2: Compute the physical properties of gas and liquid phase using an appropriate assumption for line pressure, as these properties are dependent upon pressure. Initially, the assumed pressure is the given inlet line pressure.

Step 3: Compute the values for $L\lambda\psi/G$ and G/λ which are determined by gas and liquid rates and fluid physical properties. The values of $L\lambda\psi/G$ and G/λ are then used as indices to the graphical correlation of Figure 3 to determine the flow type most likely present in the line. In the computer, Figure 3 is represented by a two-way table lookup operation. The identification of the flow type is then used to select the pressure drop equation governing that type of flow.

Step 4: Compute the two-phase pressure drop over the line length. Compute the average line pressure and compare with the previously assumed average line pressure used for the evaluation of physical properties. If the assumed and calculated average line pressures are different by more than a prescribed maximum, the computed line pressure is taken as a new assumption and Steps 2-4 are repeated.

Step 5: Compare the computed two-phase line pressure drop with 10 percent of the computed terminal line pressure. If the pressure drop is greater than

the 10 percent value, break the line length into as many segments as necessary to produce an estimated pressure drop over each no greater than 10 percent of the estimated terminal line pressure. This segmentation is necessary to insure that the assumed line pressure used at any point for computation of physical properties and gas/oil ratio is not appreciably different from that actually present in the line.

Step 6: If segmentation has been necessary, repeat the procedure of Steps 2-4 for each segment and add the segment pressure drops to find the two-phase pressure drop over the entire line.

As boundaries separating different types of flow are encountered in the systematic increase of either the gas or oil rate, flow type oscillation may occur. This is purely a computational phenomenon that arises in the following manner. On an assumed line pressure one computes the flow type, which may be, e.g., slug flow. On the next trial, using an adjusted assumed line pressure, the calculated flow type may be froth. The next iteration may return to slug flow, and so on. This type of oscillation may continue indefinitely prohibiting a final calculation of line pressure drop. Under these circumstances the computer program produces an error signal that identifies the trouble and goes to the next line rate case.

The occurrence of oscillation is not catastrophic as it simply signals a boundary condition between flow types, warning that extrapolation into the flow range involved is subject to the hazard of indeterminate flow type. A similar situation exists in single-phase oil flow between Reynolds numbers of 1000 and 2000.

The preceding calculation leads to a single pressure drop value which can be plotted as the usual characteristic line pressure curve for varying rates of both gas and oil thruput.

Illustrative plotted output data from the program is shown in Figure 4, where pressure drop values are given for 16-inch diameter pipe over an oil rate range of 0-50 MB/d at a gas rate of 35 MMscf/d. For this selection of input data, three types of flow are found to exist at different values of the data—annular, slug, and froth. Pressure drop values at 5 and 20 MB/d were not obtainable due to the occurrence of the flow type oscillation discussed above.

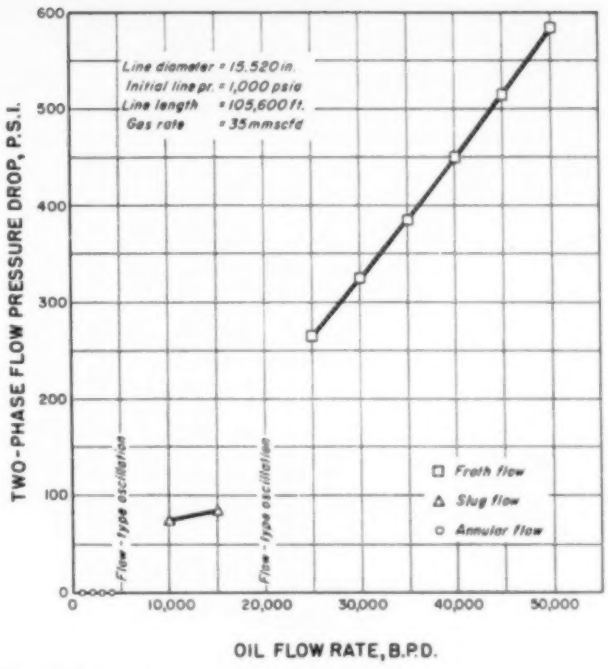

FIGURE 4—Annular-slug-froth flow in 16-inch pipe line.

It is interesting to observe that the requirement for line segmentation on occasion calls for 30 or more segments to be treated computationally. This amount of calculation, added to the trial and error solution for line pressure itself, brings the total number of arithmetical operations to hundreds of thousands and, in some cases, to a million or more. It would be practically impossible for this amount of work to be done manually. It seems proper to view the electronic computer in this application as a device enabling a degree of precision in engineering design not otherwise available.

It is certainly true that in the current research work addressed to the two-phase problem progress would be severely hampered, if not totally discouraged, in the absence of automatic computation as a tool.

Operating control of a heated oil line

The design of heated oil lines has been reported adequately in numerous articles over the past few years and nothing new is to be reported here with regard to the fundamental design concepts involved. However, in the development of an operating guide for a heated line, an unexpected characteristic of such lines was developed on the basis of extensive computational analysis which greatly simplifies operational control of the line in question and possibly others.

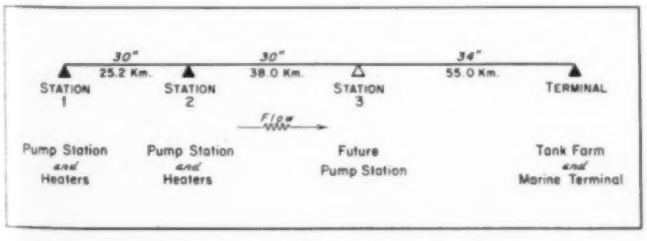

FIGURE 5—Schematic pipe line system for heated oil transportation.

The problem was as follows: Develop a simple operating guide for dispatching use to govern the selection of pumping pressures for a heated crude pipe line. Some system details are shown schematically in the sketch of Figure 5. The line is 118.2 kilometers in length and of two diameters, 30-inch and 34-inch. Projected line rate is 310 to 490 MB/d. Pumping and heating stations are located as indicated in the figure.

The general method of solution was the generation of a set of tables showing the required line friction pressure loss as a function of line thruput, inlet temperature of the

oil for each crude pumped and for each line diameter involved.

The variables include the line diameter, oil rate, oil thermal conductivity, soil thermal conductivity, wall heat transfer coefficient, ambient temperature, inlet temperature of the oil, viscosity-temperature function for the oil, oil gravity, and the distance of oil travel.

These variables are related by the expression:

$$T_2 = T_A + \frac{T_1 - T_A}{e^{5.46XKd/\varphi Q}}$$

where: T_1 = Initial oil temperature, °F
T_2 = Temperature at a point along the pipe line at distance X, °F
T_A = Temperature of surroundings, °F
X = Distance, km.
d = Pipe outside diameter, in.
e = Napierian base
K = Average heat transfer cofficient, Btu/ft² hr °F
φ = Specific gravity of oil
Q = Line thruput, bbls/hr.

The values assignable to the variables are known or may be assumed with acceptable accuracy with the exception of the soil thermal conductivity. This was determined experimentally by measurements along the right-of-way for the soil in place.

For purposes of computation, the 30-inch and 34-inch line segments were each subdivided into eighteen intervals over which soil conductivity was approximately uniform in value. These intervals were then used as computation intervals for which terminal line temperature values were calculated by Equation (1). Temperatures at the beginning of succeeding intervals were taken as the previously calculated terminal temperatures. In this fashion a temperature profile was constructed for the line for which an example is shown in Figure 6.

After the determination of both initial and terminal line temperatures for each interval, the average of the two was taken and stored in memory for the subsequent calculation of a viscosity profile for the line.

With a stored temperature profile in magnetic memory,

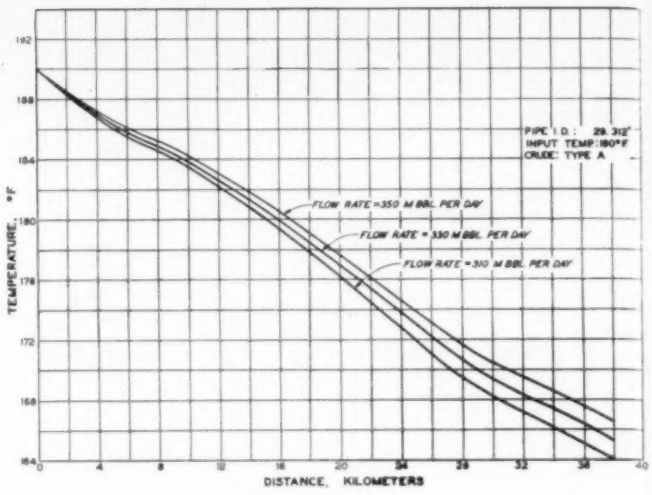
PIPE I.D.: 29.312"
INPUT TEMP: 180°F
CRUDE: TYPE A
FLOW RATE = 350 M BBL PER DAY
FLOW RATE = 330 M BBL PER DAY
FLOW RATE = 310 M BBL PER DAY
TEMPERATURE, °F
DISTANCE, KILOMETERS

FIGURE 6—Heated oil pipe line system temperature plotted versus distance.

a viscosity profile for the line was computed by the relation:

$$v = e^{(cT)-n} \qquad (2)$$

where: v = Viscosity of oil, cs.
e = Napierian base (2.7183+)
c = A constant characteristic of a given crude
n = A second constant characteristic of a given crude
T = Temperature, °R

With viscosity as a function of distance along the line available in memory, it was then possible to calculate friction pressure drop across each of the eighteen computation intervals to develop a pressure loss profile for the line segment. A plot of such a profile is shown in Figure 7.

Inspection of numerous pressure drop profiles indicated that the line pressure drop for a given line diameter, crude, line rate, and input temperature was very nearly linear with distance, as is true in the common isothermal flow. This unexpected result permitted the tabulation of pressure drop per kilometer values as a function of line rate, line diameter, and input temperature to produce a set of tables to be used by operating personnel in setting pumping pressures. The table format is shown in Table 1.

In use, a set of ten tables covering two line diameters and five crude types can be used to supply pressure drop

TABLE 1—Heated Oil Pressure Drop Correlated With Flow Rate and Input Temperature

Pipe I.D.: 33.250"
Crude: Type A*

PRESSURE DROP, PSI PER KILOMETER

Flow Rate M Bbl Per Day	INPUT TEMPERATURE, °F								
	130	140	150	160	170	180	190	200	210
490	28.319–0	19.098–0	13.450–35	11.471	10.568	9.784	9.102	8.503	7.976
470	27.400–0	18.508–0	12.882–32	10.698	9.858	9.129	8.493	7.936	7.445
450	26.482–0	17.920–0	12.395–27	9.947	9.168	8.492	7.902	7.385	6.929
430	25.566–0	17.334–0	11.948–22	9.432–47	8.501	7.876	7.331	6.852	6.429
410	24.651–0	16.749–0	11.590–14	8.920–42	7.854	7.279	6.777	6.335	5.945
390	23.740–0	16.168–0	11.176–12	8.436–38	7.231	6.703	6.242	5.836	5.478
370	22.830–0	15.589–0	10.836–6	8.037–32	6.740–51	6.147	5.725	5.355	5.027
350	21.924–0	15.014–0	10.528–0	7.667–27	6.232–47	5.612	5.229	4.892	4.594
330	21.020–0	14.442–0	10.157–0	7.337–22	5.845–42	5.097	4.751	4.446	4.176
310	20.120–0	13.876–0	9.791–0	7.059–16	5.518–35	4.713–47	4.294	4.019	3.776

NOTE: A number following a hyphen is the distance in kilometers from Station 2 to the point at which laminar flow (Re <1000) begins; all other flow is turbulent.
* 0.991 sp. gr. @ 60° F.

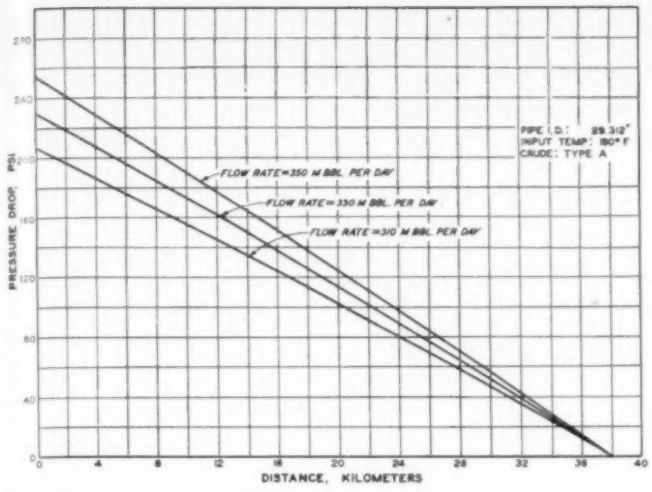
PIPE I.D.: 29.312"
INPUT TEMP.: 150° F
CRUDE: TYPE A
FLOW RATE=350 M BBL. PER DAY
FLOW RATE=330 M BBL. PER DAY
FLOW RATE=310 M BBL. PER DAY
PRESSURE DROP, PSI
DISTANCE, KILOMETERS

FIGURE 7—Heated oil pipe line system pressure drop versus distance.

values for evaluating the expression:

$$P = \Sigma L_i^{30} \cdot \Delta P_i^{30} + \Sigma L_i^{34} \cdot \Delta P_i^{34} + P_{PM} \qquad (3)$$

where: i = Identification number of a batch in the line

P = Pumping pressure, psi

L_i^{30} = Length of batch i that resides in the 30-inch line, km

L_i^{34} = Length of batch i that resides in the 34-inch line, km

ΔP_i^{30} = Table value of pressure drop for crude batch i in the 30-inch line, psi/km

ΔP_i^{34} = Table value of pressure drop for crude batch i in the 34-inch line, psi/km

P_{PM} = Required arrival pressure at the line terminal, psi

Thus, the computer simulation of a heated line carrying different kinds of crude oil can be used to generate a set of operating tables that permit the daily or hourly setting of pumping pressures by dispatching personnel.

The apparent complexities of variable soil thermal conductivities, temperature and viscosity variation along the line, and the resulting complexity in the determination of line pressure drop were unexpectedly simplified by the approximately linear line friction loss when actually calculated in detail.

Hydraulic computation with profile

The Problem: The hydraulic calculations required to determine the operating pressures and power requirements for a multi-station pipe line over rough terrain are generally obtained by graphical procedures. For a detailed study of such a line where a number of stations are considered, the line profile is highly irregular, and pressure relief on downhill runs appears necessary, the graphical procedures are likely to be costly in terms of man-hours of labor required for the analysis.

The object was to avoid the graphical labor required for such studies through the direct simulation of the operation of a generalized rough terrain pipe line. In addition to the factors mentioned above, computational recognition was desired for the effect of extra-wall pipe on the permissible operating pressures in the line.

Other elements for recognition in the simulation included the usual restrictions on suction and discharge pressures. The line profile for simulation was to be represented by not more than 150 pairs of milepost-elevation coordinates. A maximum of 20 pump stations and 10 pressure relief stations were to be represented.

The Simulation: The operational simulation is initiated with the usual data read-in which includes a set of not more than 20 thruput values for which individual station operating pressures and power requirements are desired as output. The critical problem is the determination of a set of operating pressures for each thruput which will not violate suction and discharge pressure restrictions nor the maximum permissible line pressure at any point along the line. In addition, sufficient line pressure should exist at all high points of the system to maintain the fluid in the liquid phase.

The forced violation of any of the pressure restrictions above by a particular thruput condition will be reported with identification of the type of pressure violation involved as well as its location.

The appearance of the output data from the simulator is shown in Table 2 for a single line rate.

The simulation is executed by a three-pass program with the second pass containing the fundamental hydraulic simulation of the pipe line.

What the Computer Does. The computer program examines each profile coordinate pair, starting with the first

TABLE 2—Hydraulic Computation With Profile Program No. P35—Thruput 60,000 Bbls/Day

Pumping Station No.	Suct. Press PSI	Disch. Press PSI	Net Press PSI	Power Required BHP
1	0.0	581.0	593.5	756.7
2	25.0	671.0	658.5	839.6
3	0.0	0.0	0.0	0
4	338.2	663.0	337.3	430.1
5	250.0	610.6	373.1	475.7
6	25.0	734.4	721.9	920.4
7	25.0	801.6	789.1	1006.1
8	142.0	0.0	0.0	0
Pressure Relief Station No.				
1	587.0	48.8	525.7—	670.3—
2	571.8	60.8	498.5—	635.6—
3	839.2	204.8	621.9—	792.9—
Total Power Required				4428.6

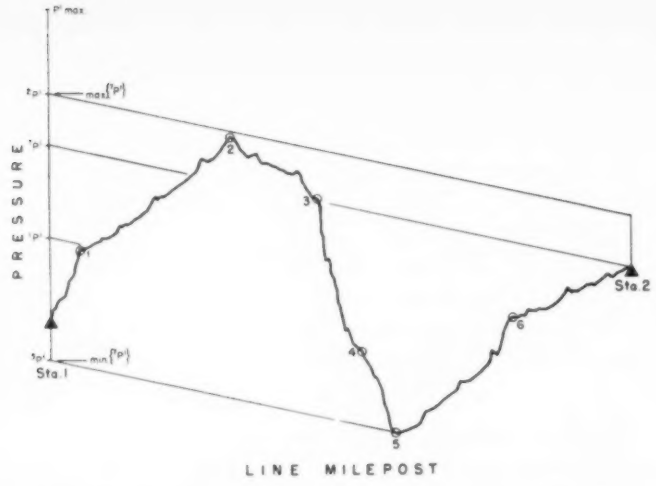

FIGURE 8—Basic elements of hydraulic computation recognizing line profile.

station, to determine the discharge pressure required to reach the given point on the line. Referring to Figure 8, it can be seen that the discharge pressure to reach the first coordinate downstream from Station 1 can be calculated as follows:

Multiply the pressure drop per mile associated with the given thruput times the line distance and add the pressure equivalent of the elevation at the coordinate point. The resulting required discharge pressure is designated $^{1}P^{1}$ where the leading superscript refers to the pumping station considered and the following superscript refers to the downstream coordinate point.

The examination of coordinate pairs proceeds systematically downstream and a required discharge at the upstream station is determined for each. In the calculation a constant pressure of 14-25 psi is also added to the line loss and elevation values as a "vaporization control" pressure. This pressure is designed to maintain liquid phase in the pipe line at system high points.

As the line scanning process described proceeds to the next pump station, a record is kept of the maximum and minimum values of the computed discharge. It can be seen from Figure 8 that the maximum value found, $^{2}P^{1}$, is the required discharge and that it in turn determines the value of the incoming suction pressure at the succeeding station. It is also seen that the difference between the maximum and minimum required pressures, $^{2}P^{1}$-$^{5}P^{1}$, is the value of the maximum pressure to which the line is subjected at any point between Stations 1 and 2.

If it is found that the maximum line pressure exceeds the standard pressure limit of the pipe (stored in memory), then the program makes a special interrogation of the coordinate point, number 5 in this case, to see whether extra-wall pipe is installed at this point (also a matter of record in magnetic memory). If extra-wall pipe strong enough to contain the required operating pressure is in place, the thruput is accepted as operable. If the computed line pressure exceeds the line limit in any case, the thruput is rejected as inoperable and a special print-out occurs identifying the nature of the trouble and its milepost location.

The kind of inspection for violation of line pressure restrictions just described is actually performed for each coordinate point on the line. This check guarantees that no part of the line will be subjected to excessive stress.

Pressure Relief Stations. A requirement for the operation of a pressure relief station is recognized in the following manner: In the examination of line coordinates for line pressure exceeding line limit, when excessive pressure is detected a search is made upstream to determine

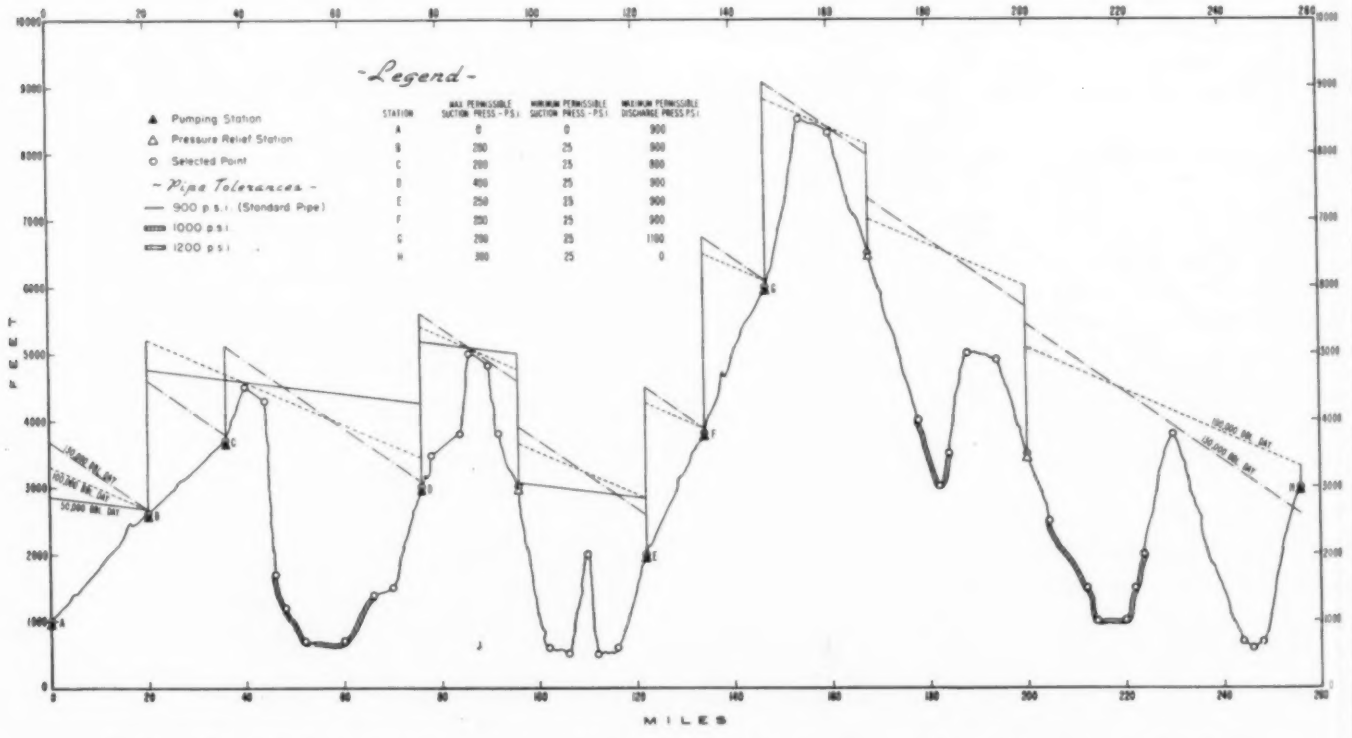

FIGURE 9—Plotted computer output for an arbitrary pipe line, showing pump stations and pressure relief stations.

whether a pressure relief station location has been passed since the last pumping station. If a pressure relief station has been passed, it is brought into operation and serves to reduce line pressure just sufficiently to avoid exceeding the line limit and at the same time preserve sufficient pressure to clear intervening high points.

The output of the simulation program is shown graphically in Figure 9 which illustrates the capabilities of the program using a fictitious line profile. The profile used was selected to exercise all the logical processes of the simulation. Three thruput conditions are shown represented by the three hydraulic gradient profiles identified as 50, 100, and 130 MB/d. The line diameter was 15.375-inch and oil properties were 4.00 cs viscosity and 0.69 specific gravity.

Difficulty arises at the 50 MB/d rate at the first pressure relief station, as it is necessary for the relief station to pull its discharge pressure below the vaporization control pressure in order to deliver at the next pump station, Station E, at an acceptable suction pressure. The program output for the 50 MB/d rate would identify the trouble and its location.

No difficulty is experienced with the 100 MB/d rate, and delivery to the terminal is physically possible. The 130 MB/d rate runs into trouble as the discharge pressure from the pressure relief station immediately upstream from the terminal is required to be low enough to protect the line at the subsequent low elevations, forcing an indicated negative suction pressure at the terminal. Hence, 130 MB/d is found to be an inadmissible thruput condition.

The type of information developed in the preceding discussion applies of course to projected pipelines, and can be of great value in the design of a new line. The simulation program is of further value in operations engineering in developing power and operating pressure requirements at all stations as a function of thruput. Projections can also be made easily indicating the values of line rate at which successive stations will necessarily be brought into operation.

The computer running time for a simulation is approximately 25 minutes during which 20 thruput rates can be simulated for a 620-mile pipe line crossing the Rocky Mountains.

Economic simulation: Optimization of power cost

The Problem: The annual expenditure of approximately $1,500,000 for electric energy for pumping power on a pipe line system suggested itself as an appropriate subject for economic study. It had been recognized for some time that a multi-station pipe line purchasing electric power under different contract schedules from public utilities at different station locations offered the possibility of optimization (i.e., minimization) of power cost. This optimization could be accomplished by an appropriate allocation of energy usage among the several stations.

The problem was to determine the allocation of total energy requirement to be made to each of the several pump stations so that the total energy cost for a month of operation would be at a guaranteed minimum. The line itself is the same system described in the previous discussion of automatic control simulation, a 10-station, 438-mile, 22-inch diameter line carrying 240-280 MB/d.

The Simulation Program: The computer simulation was required to contain exact duplication of the principal features of the system in order to achieve the required accuracy of analysis. The line was represented by the usual parameters of inter-station lengths, diameter, and elevations recognized at station locations. The oil properties were approximated with a single representative viscosity and gravity. The stations were represented by a set of centrifugal pump head-capacity curves for the four pump units at each station. A single characteristic efficiency-capacity curve was used to furnish this function for all pumps.

The critical cost function represented by the industrial power rate schedules on which energy was purchased were represented by program subroutines capable of generating exact power costs. These contract subroutines contained the rate schedule itself plus such monthly adjustment features as power factor, historical power demand value, and fuel adjustment factors. Five contracts covered all energy purchased on the system.

The basic scheme of the simulation is a logical search procedure which develops all physically possible assignments of pumping units which will develop the required monthly thruput in the system. The search procedure finds all power levels at a given station which will develop a discharge pressure no greater than the line limit and produce a suction pressure at the next station downstream within the tolerance on that operating pressure.

The program output data consists of the power level and operating pressures at each station combined in sets for the ten stations, each such set of operating data constituting a fully operable scheme for line operation at the given thruput rate, viscosity, and gravity.

The simulation of the line operation for a single thruput condition commonly develops between 500 to 1,000 feasible schemes for each of which a different energy cost is found.

The operating data described above, containing power demand and energy use for each station, are then used to develop power costs for each of the stations for each of the previously computed operating schemes. A sum of energy costs for the system is made for each scheme and the lowest cost of all the schemes is identified and reported. In addition the output data contain all operating pressures and power levels at the 10 stations. This data then permits the operation of the line for the month at a minimum cost for the energy purchased.

The number of arithmetical operations for a typical

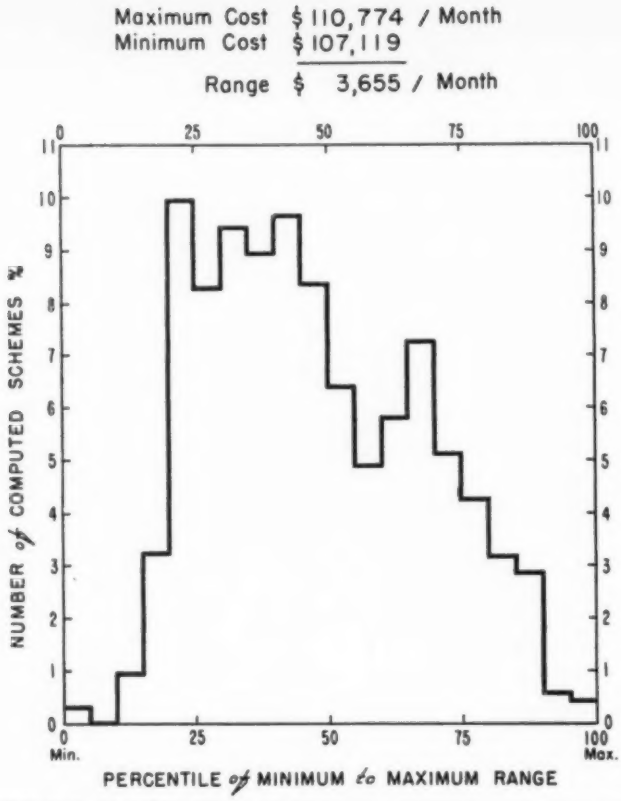

FIGURE 10—Distribution of computed power costs for a pipe line system operating at 240,000 barrels per day. A test run of the simulation based on this projected thruput yielded 631 different feasible line operating schemes.

simulation run is estimated at 8 million. The initial computer running time for the optimization was 20 hours. However, program modifications were eventually developed which disabled portions of the simulation to bypass schemes which logic indicated could not possibly be improvements over previous schemes. This program improvement eventually resulted in a reduction in computer running time to two hours.

Results: The computer simulation permitted a study of the economic hazards involved in attempting to operate a line in the absence of a comprehensive procedure, such a computer optimization, for control of power costs. Some of the results of the study are given here.

A test run of the simulation based on a projected thruput rate of 240 MB/d yielded 631 different feasible line operating schemes. Of these, the maximum system power cost for the month was $110,774. The optimum scheme had a power cost $3,655 less than the maximum. The distribution of the computed power costs associated with the 631 different operating schemes is shown in Figure 10 in the form of a frequency distribution. The plot shows the percent of the schemes which had costs in each 5 percent interval of the $3,655 range, minimum to maximum.

The cost distribution plot suggests that an unskilled selection of an operating scheme would probably yield a cost of about $108,764. As the minimum cost available would be $107,119, the unnecessary cost incurred with such an unskilled scheme selection would be $1,650 for the month, or 1.5 percent of the total. The worst possible selection of an operating scheme, of course, would incur $3,655 of unnecessary cost for the month amounting to 3.4 percent of the total.

Current work. The simulation of oil pipe lines is under active development by a number of companies. Recent literature reports work on scheduling, rough terrain hydraulics, and other phases of pipe line analysis.

Our own current work includes program development for line scheduling, tank farm simulation using Monte Carlo methods, hydraulics recognizing individual batch properties, and the application of various mathematical programming methods to power optimization.

Ultimate Objectives. In general, this new work is intended to bring the powerful new methods of modern mathematics and automatic computation into practical use in the management of pipe line operations. A working objective at this point of experience appears to be the ability to perform the following task:

> Schedule, dispatch, optimize power cost and minimize duty on tankage for a multi-station, multi-injection, and multi-terminal pipe line recognizing the hydraulics of rough terrain and physical properties of individual batches of oil. Schedules for lines will include batch compositions by crude field and permit a 90-day forward projection.

Associated with such a comprehensive simulation would be the ability to develop other data under projected operating conditions for purposes of economic study.

About the Author

T. R. Young joined Shell Pipe Line Corporation in 1951; since 1955 he has been engaged in the application of electronic computation to economic and technical problems. Previous experience includes a position with University of Wichita as a representative for the university's Foundation for Industrial Research.

He was graduated from the University of Michigan in 1943 with a B.S. degree in chemical engineering and joined The Texas Company's Beacon Research Laboratories where he was concerned with aviations fuels research.

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AN API FEATURE

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S. D. Williams has been controller of Sohio Pipe Line Co. since 1955, and assistant controller of Standard Oil of Ohio since 1954. He received his education at James Milliken University and the University of Illinois. He is a member of the Controllers Institute, the Mid-Continent Oil and Gas Association, and chairman of the Accounting Practice Research Committee of API Division of Finance and Accounting.

API Symposium on "Responsibility Accounting"

Basically, responsibility accounting refers to a method of charging costs or crediting revenue items to the activity which is held responsible for those costs or revenues. While this seems simple, it can be somewhat complex, depending on the organization, policies and personnel of various companies. Here are the views of three key men in this field.

A Unique Opportunity for the Manager and Accountant

By **W. F. Krick,** Chief Accountant
Pure Transportation Co., Chicago

THE COLD SPECTRE of competition has placed every enterprise in the uneasy position of making hard, searching evaluations of what it is doing, how it is doing it and can it be done cheaper. To get answers, and correct answers, to such significant questions is of overwhelming importance. It is essential to making daily decisions as well as the equally important adjunct to establishing long-range decisions.

Responsibility Accounting, according to the popular understanding of the term, is a means of supplying accounting information to those who are directly responsible for the expenditure of funds. In some ways, it is the philosophy that every person in an organization who has the authority for committing money should be given a periodic score or tally of what he has done.

Leading authorities believe the development of the concept of *responsibility accounting* represents an important milestone in the use of accounting-based data for control. Effective control of business operations requires a

very definite and particular approach to account classification followed by a minimum of allocation and with an over-all close tailoring of the system to the organizational structure of the firm—the assigned authority and responsibility throughout the firm. Since cost control is achieved through people and not through things, accounting-based data must be reported primarily in terms of the responsibilities of people for internal control purposes.

To be most useful to management, accounting information must be tailored to the needs of those who make decisions at the various levels of responsibility. In order to accomplish best this tailoring process, psychological and personnel problems must be recognized. Accounting information does not itself effect the proper business decision. It finds usefulness only to the extent that there is communication to responsible individuals in such a way as to motivate these individuals to appropriate action. Thus, its usefulness is dependent largely upon adequate oral and written communication and a proper attitude of receptiveness on the part of management.

What is the role of the accountant in supplying data to management? In essence, he has three facets of responsibility. He should provide financial data on what has occurred; he should interpret to management the data which he prepares; he should project future action on the basis of past performance based upon present conditions. Only when the accountant has acted in these capacities has he discharged satisfactorily the full content of his job.

When considering the format, style and content of reports intended for cost evaluation, today's accountant must recognize that the approaches to cost statements are not the same as those made for conventional financial reporting. The ends to be served are not the same. For this reason, the accumulation of data and information should be changed to provide honest and intelligent answers to best picture the cost results which management needs in order to act with the greatest comprehension and direction.

The accountant should provide whatever data or reports necessary to management so that it may make the needed decisions called for by the circumstances and further report in such a way that the responsible individuals will be properly motivated to appropriate action.

In the past, a function of the accountant frequently overlooked has been his unique, significant and unduplicated ability to interpret the material which he developed. Recent trends in reporting styles with their strong emphasis upon graphic presentations of charts and diagrams give strong indication of the accountant's awareness of his function of interpretation.

Interpretation of results also is provided through comparative data. The presentation of cost data in adjacent columns for a number of successive time periods enables the reader to note quickly the directional movement of the account balances. Modification of the presentation to include amount and percent of change gives a weighting to the movement. Such an arrangement, while going part-way in supplying cost data, does not, however, identify the forces responsible for variations nor measure their relative magnitude.

Comparisons can be developed involving segments of pipe line within the same facility group as well as between facility groups. This can be accomplished through development of common size relationships. These can be expressed in terms of cents per 100 barrel miles, in percentages of the various classes of expense to total expense or direct comparative percentages. Again, these are only indicative factors and require interpretation of the causes of involvements precipitating changes from desired trend movements.

The accountant must provide accurate and imaginative cost information to the various levels of operating management; and interpret the results to give their true meaning to these individuals.

The situation can be likened to that of a medical diagnostician and his patient. This specialist makes his examination and discovers certain symptoms of disorder. Upon proper reflection the malfunctions are correlated and appraised, following which a diagnosis of the disease or disorder is finally established. With this information, the patient's doctor can then determine the appropriate cure.

It is possible that accountants are the oldest group of specialists who have served management in business. Quite often they have been looked upon as necessary evils—cajoled and cultivated in times of trouble, ignored in prosperity, tolerated but unloved. The story is told that the elder Henry Ford, who may have been the principal of this school, consistently refused to give additional office space to his accountants. "Keep 'em crowded," he said. "Maybe they'll get discouraged and leave."

The record-keeping requirements imposed upon the pipe line industry by federal and/or state regulatory bodies has made an active and alert accounting organization a vital part of every company. Income tax and its infinite problems has added to the functional importance of the accounting organization.

Yet, in both instances, if these be the sole activities of this group, an economic waste is occurring of the first magnitude. Harking back to my first comments about the cost considerations of today's business climate, the failure to use your accounting group for effective and pertinent report service can be a serious criticism of management. It's like starving to death while Grandmother's Thanksgiving dinner is breaking the legs on the dining room table.

What Does Pipe Line Management Need for Operating Cost Control?

By G. M. Johnson, Vice President
Sinclair Pipe Line Co., Independence, Kan.

LET'S DISCUSS pipe line cost statements and the detail required to make them useful as a control medium. The accumulation of costs, as provided for in the Interstate Commerce Commission's "Uniform System of Accounts," under categories such as Maintenance, Transportation, Other Expenses, etc., is of little value for this purpose.

Until recent years, it was the practice to provide management with such statements and it was difficult to

STATEMENT OF GATHERING LINE COSTS
DISTRICT _____ (Location)

YEAR 1960

Source of Costs	First Quarter	Second Quarter	Third Quarter	Fourth Quarter	Total	Jan.	Etc.
Barrels Gathered							
Barrels Per Day							
Miles of Pipe							
Total Expense (before F.I.T.) $							
Cents Per Barrel							
Tariff Rate (Cents)							
Profit or (Loss) $							
Direct Costs							
Miscellaneous Expense $							
Line Pipe							
Material, Supplies & Services							
Rentals & Leases							
Power, Fuel & Utilities							
Motor Vehicle Expense							
Contract Work							
Employees, Personal Expense							
Employees Benefits:							
Non Labor) (These two categories could be combined under a total for							
Labor) "Employee Benefits.")							
Co. Labor-Field Payroll							
Co. Labor-Confidential Payroll							
Sub-Total $							
Cents Per Barrel							
Taxes (except F.I.T.)							
Depreciation							
Total Direct Costs $							
Cents Per Barrel							
Indirect Costs							
Prorated Depreciation $							
Prorated other costs except Labor							
Prorated Company Labor							
Non-operating Charges							
Non-operating Credits							
Total Indirect Costs $							
Cents Per Barrel							

FIGURE 1—This statement should be made quarterly by adding three months to a master sheet each quarter. At the year end, 12 months and four quarters can be examined in one statement. At the end of the year, and after the statement has been studied, the monthly detail can be removed, leaving the quarterly and yearly totals to be retained for filing and future reference.

isolate the source of increasing or high costs. It provided dollars and/or cents per barrel under these designations, but did not break it down into categories such as material, labor, power, etc., so that the offending source could be readily identified without further research.

Outside of our general office that part of management and the supervisors who control the greater part of the company's operating expense are division manager, district superintendent and connection foreman. A division manager has over-all supervision of the system in one state or several states. A district superintendent has charge of the system in several counties within a division, consisting of a gathering area and a rather long section of trunk line. Each superintendent's district is subdivided into several connection foreman areas, either gathering or trunk or both.

These three men control the spending of the money which adds up in the operating expense column. The transportation of crude oil and products is a highly competitive business and it is the responsibility of these three individuals, as well as higher management, to keep costs at a minimum, especially during the past decade when inflation affected everything except pipe line tariffs.

It is, therefore, necessary that the Accounting Department prepare cost statements, which will, at a glance, expose districts and categories of high costs and those where costs are increasing.

Management would like to have more detail than is practical to produce and there is considerable doubt that a separation of costs into small operating units has any useful purpose. How frequently should cost data be produced? *Monthly* statements would be ideal for both gathering and trunk operations, but figures may be misleading because of delays in booking current expenditures. *Quarterly* statements must therefore suffice. For gathering systems, it is preferable that monthly charges be recorded and totaled for each quarter, whereas for trunk lines, only quarterly figures need be developed.

It is important that costs be accumulated in a manner to provide rapid analysis requiring a minimum of further research. To accomplish this, a form showing costs by sources is suggested for gathering districts as illustrated in Figure 1. By progression, on a monthly-quarterly basis, a trend or comparison is immediately discernible and unusual costs or increases in each category can be investigated and an effort made to apply controls with no more delay than three months.

The desired basic trunk line cost statement could be in the form as shown in Figure 2 entitled "trunk line costs by movements." It is designed and intended to summarize costs by tariffs or movements. This form, as illustrated is designed primarily for crude oil movements wherein a refinery is usually the single reception point served from various origins. For products shipments the tabulation under "movement" should be reversed by showing first the origin point, usually a refinery, and then, under it, list the various delivery locations with applicable tariffs.

Referring to Figure 2, 80 is the issuing carrier, 1 identifies the regulatory body such as I.C.C., and 175 is the tariff number. Further code numbers could be added to indicate routing. This statement can be machine processed so its detail is limited only by the tape width. A refinement would be to add a column for miles for each tariff from which the cost per 100 barrels per mile could readily be determined. This statement should be prepared semi-annually with the issuance of one statement for the first six months and another for the entire year, and will readily identify profit and loss movements. However, it

TRUNK LINE COSTS BY MOVEMENTS - FIRST SIX MONTHS OF 1960 (OR YEAR 1960)

Movement	Tariff	Consignor	Barrels Delivered	Operating Expense Other	Operating Expense Power	Deprec.	Interest	Taxes	Total Costs	Tariff Rate	Credits	Profit or (Loss)
(Destination) (Reception Points) Etc.	80-1-175 Etc.	(Shipper) Etc.										

Repeat for each destination.

FIGURE 2—Note that Operating Expense charges are to be expressed in cents per barrel carried to two decimal places. Tariff is also in cents per barrel. Tariff prefix identifies issuing carrier and regulatory body. Taxes or totals do not include federal income taxes. Profit or Loss includes credits.

does not provide enough detail for the source of costs so a supplemental statement by trunk line accounting districts would be required.

This supplemental statement should be made in the same form as Figure 1 (Gathering) except that the top heading should be limited to barrels and cost per barrel. The Direct and Indirect Costs should be accumulated by sources the same as for the gathering districts. However, there are many more trunk accounting districts as compared to gathering districts, so the trunk form should be designed for machine preparation. It would, of course, be desirable to show these costs by months by quarters, as in Figure 1, but if this resulted in manual preparation, a compromise is to produce the total costs for the current quarter and the three previous quarters to show a trend.

Symbols or code numbers could be used for sources of cost to conserve space and limit the form to letter size. Barrels should be in whole numbers and cost in whole dollars. Costs by Movements can then be traced through the various accounting districts to determine where controls need to be applied. To simplify the procedure, it is desirable to have as few districts as possible, from an accounting standpoint, and yet have as many as may be required to readily identify the location and cause of excessive costs. These areas could be limited somewhat by assigning a district number to more than one trunk line inter-station segment insofar as state lines, reception points and delivery points will permit. In addition, each trunk line station must be a separate accounting location.

Gathering expenses (Figure 1) are subdivided into direct and indirect costs. The sub-total under direct cost is important to the supervisors in the field as it represents the expenses over which they have direct control. There is not much they can do about ad valorem taxes and depreciation. They do have some control over a part of the indirect costs, at least to the extent that their office expense is involved as it must be allocated to the several accounting districts within their supervision. General office costs are indirect charges and are allocated in a like manner in proportion to all other expenses within the district. These later expenses are, to a great extent, determined by field operations and therefore indirectly controlled by field men although it is not within their prerogative to determine their extent, hence the need for a sub-total of field controlled expenses under direct costs.

As most gathering districts are large in area and include several oil fields, to which extensions have been made, the ideal subdivision would be one of assigning a separate accounting district to each extension. This would permit isolating costs to a particular location and expose those where costs become excessive in proportion to revenue as production decreases. It would also provide a criterion for establishing gathering tariff rates for the different fields commensurate with local costs. As it is, the transportation charge usually covers an extensive area containing a number of field connections, some being unprofitable. Whenever operating management proposes smaller area district assignments, the Accounting Department rises up in opposition as it further complicates its record keeping. They may be justified in that assumption because it is a question of how far to go with detail.

By and large, it is our present consideration that the method here described is the minimum. As machine application to assembling these data is expanded, the time required to produce them will be shortened and perhaps more detail made available. However, the manager should not overlook the fact that he is limited by himself and time, so statements and reports should likewise be limited to the bare essentials to maintain a profitable operation.

What are Pipe Line Accountants Doing for Operating Cost Control?

By S. D. Williams, Controller
Sohio Pipe Line Co., St. Louis, Mo.

ACCOUNTANTS HAVE BECOME acutely aware of the need for the control of costs by the people who are responsible for incurring them and the ideal system provides that each so-called responsibility center is charged or credited only with those cost and revenue items for which its head is held responsible. This has been the basis for a significant amount of research and development concerning the structure of the accounting system within the framework of responsibility accounting. This has followed three general trends:

1. Measurement of the responsibility center by using only controllable revenues and costs.
2. Measurement of the responsibility center by controllable revenues and costs plus a portion of general administrative overhead or a management fee to cover specific services.
3. Measurement of the function by classification of costs according to the function within organization lines. Where specific costs are identifiable by functions or where distribution can be made on a direct relationship to a function, the general overhead allocation is reduced to a minimum amount.

The second general plan appears to be the most common practice at the moment. Here, the head of a responsibility center or function is charged with those costs which he controls. Then, he is also charged with those costs over which he has a significant influence, although it is recognized that he may never have sole responsibility for any element of these costs.

Up to this point, there doesn't seem to be a great deal of disagreement between the operating men and the accountants. We find in practice, however, that when costs over which he has no direct influence are added to his center, differences of opinion commence to appear. These are costs which management wishes a manager to be concerned about and they theorize that his concern may indirectly lead to better cost control. Obviously, there has to be some beneficial reaction when a supervisor recognizes the large amounts in indirect costs which are necessary to support him in his function. There are dangers in connection with this, also. For a manager may conclude that the costs which he he can control are so small in relation to indirect costs which he can

do little or nothing about, that it is useless for him to be concerned about them at all.

In any event, if management wishes these costs to be distributed to various responsibility centers, it is important that they be set out clearly and differentiated from the costs that the head of the center is expected to control. In practice, allocation of general overhead costs are made on one of several bases, or a combination of these. Distributions may be made on the basis of:

1. Personnel.
   a. Number of employes.
   b. Dollar payroll.
   c. Actual hours worked.
2. Controllable costs.
3. Physical assets.
   a. Net fixed assets.
   b. Gross equipment account.
   c. Equipment utilization.
4. Profits.
5. Material use.
6. Capacity.
7. Current investment in the center or function.

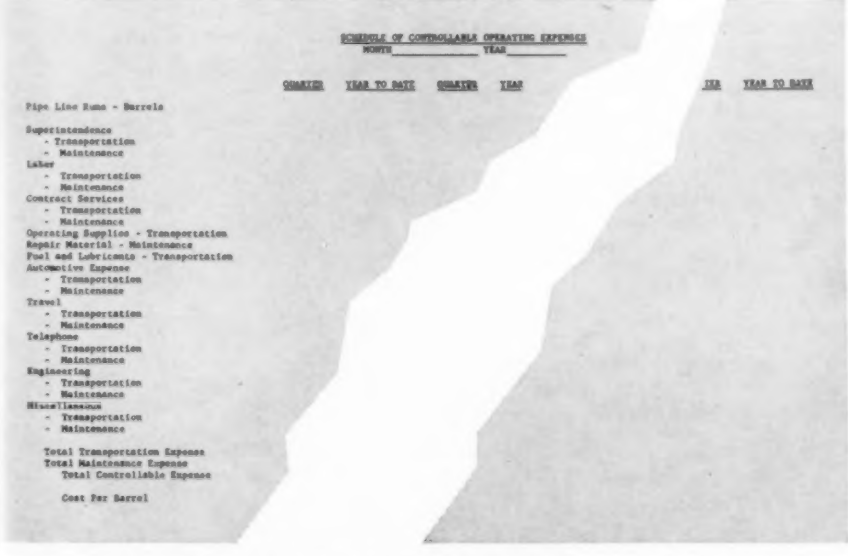
Now, more specifically in the area of what has been done by the accountant for pipe line operations, here are samples of three separate sets of statements which indicate substantial progress in the development of the responsibility accounting concept:

DETAILS OF EARNINGS AND EXPENSE

Month _____ 19___
District _____ Dist. No. ___

	This Month		Year to Date	
	Amount	Per Bbl.	Amount	Per Bbl.
Gathering Revenue				
Trunk Revenue				
Total Revenue				
Total Field Expense				
Net Earnings for District				
Superintendence				
Repairs of Pipelines				
Changing of Line Construction				
Repairs of Buildings				
Repairs of Pumping Stations				
Repairs of Oil Tanks				
Repairs of Delivery Facilities				
Repairs of Communication Systems				
Repairs of Office Furn. and Equip.				
Repairs of Vehicles and Work Equip.				
Repairs of Other Property				
Other Expenses				
Total Gathering Maintenance				
Superintendence				
Operation of Pipelines				
Operation of Pump Stations				
Operation of Oil Tanks				
Operation of Delivery Facilities				
Operation of Communication Systems				
Other Expenses				
Total Gathering Operation				
Total Gathering Expense				
Superintendence				
Repairs of Pipelines				
Changing of Line Construction				
Repairs of Buildings				
Repairs of Pumping Stations				
Repairs of Oil Tanks				
Repairs of Delivery Facilities				
Repairs of Communication Systems				
Repairs of Office Furn. and Equip.				
Repairs of Vehicles and Work Equip.				
Repairs of Other Property				
Other Expenses				
Total Trunk Line Maintenance				
Superintendence				
Operation of Pipe Lines				
Operation of Pump Stations				
Operation of Oil Tanks				
Operation of Communication Systems				
Other Expenses				
Total Trunk Line Operation				
Total Trunk Line Expense				
Total Field Expense				
Oil Shortage-Gathering				
" " -Trunk Line				
Barrels Gathered				
" Transported				
Barrels Handled				

This report reflects gathering line and trunk line revenue, controllable costs, and net earnings by district. The revenue from trunk lines is assigned to districts on a barrel-mile basis, determined for each tariff. These reports of district earnings and expense are prepared monthly.



SCHEDULE OF CONTROLLABLE OPERATING EXPENSES
MONTH _____ YEAR _____

	QUARTER	YEAR TO DATE	QUARTER	YEAR		TEAR	YEAR TO DATE
Pipe Line Runs - Barrels							
Superintendence							
- Transportation							
- Maintenance							
Labor							
- Transportation							
- Maintenance							
Contract Services							
- Transportation							
- Maintenance							
Operating Supplies - Transportation							
Repair Material - Maintenance							
Fuel and Lubricants - Transportation							
Automotive Expense							
- Transportation							
- Maintenance							
Travel							
- Transportation							
- Maintenance							
Telephone							
- Transportation							
- Maintenance							
Engineering							
- Transportation							
- Maintenance							
Miscellaneous							
- Transportation							
- Maintenance							
Total Transportation Expense							
Total Maintenance Expense							
Total Controllable Expense							
Cost Per Barrel							

This is a quarterly report showing controllable costs, overhead, ad valorem taxes, and depreciation and is made up for each owned gathering system, trunk line station, and trunk line section. Revenues are not shown. Overhead is allocated on the basis of controllable costs. Ad valorem taxes and depreciation are distributed on the basis of plant investment.

How 3 Companies Handle Responsibility Accounting

Company A

COST STATEMENT
QUARTER 19___
Station No. ___

DIRECT EXPENSE	Quarter	Year to Date
MAINTENANCE LABOR		
Superintendence		
Repairs of Pipe Lines		
Repairs of Buildings		
Repairs of Pumping Stations		
Repairs of Oil Tanks		
Repairs of Del.Facilities		
Repairs of Comm.Systems		
Repairs of Other Property		
Rep. Veh. & Other Work Equip.		
Total Maintenance Labor		
MAINTENANCE MATERIAL & EXP.		
Superintendence		
Repairs of Pipe Lines		
Repairs of Buildings		
Repairs of Pumping Stations		
Repairs of Oil Tanks		
Repairs of Del. Facilities		
Repairs of Comm.Systems		
Repairs Off. Furn. & Equip.		
Rep. Veh. & Other Work Equip.		
Repairs of Other Property		
Total Maint. Mat. & Exp.		
OPERATION LABOR		
Superintendence		
Operation of Pipe Lines		
Operation of Pumping Stations		
Operation of Oil Tanks		
Operation of Del. Facilities		
Operation of Comm. Systems		
Total Operation Labor		
OPERATION SUP. & EXP.		
Superintendence		
Operation of Pipe Lines		
Oper. of Pump Sta. - Fuel & Pwr.		
Oper. of Pump Sta. - Miscl.		
Operation of Oil Tanks		
Oper. of Del. Facilities		
Operation of Comm. Systems		
Other Expense		
Total Oper. Sup. & Exp.		
TOTAL DIRECT EXPENSE		
Direct Exp. per Bbl. (cents)		
Percent of Total Direct Exp.		
INDIRECT EXPENSE		
Ovhd. & Tax (Excl.Inc. & Transp.)		
Ad Valorem Taxes		
Depreciation		
Oil Shortage		
TOTAL INDIRECT EXPENSE		
Indirect Exp. per Bbl. (cents)		
GRAND TOTAL EXPENSE		
Total Exp. per Bbl. (cents)		
Barrels Handled		

This is also a quarterly report which reflects only controllable costs for each jointly owned gathering system, trunk line station, and trunk line section. Revenues are not set out. Costs are summarized by total crude system and total products system and is then consolidated.

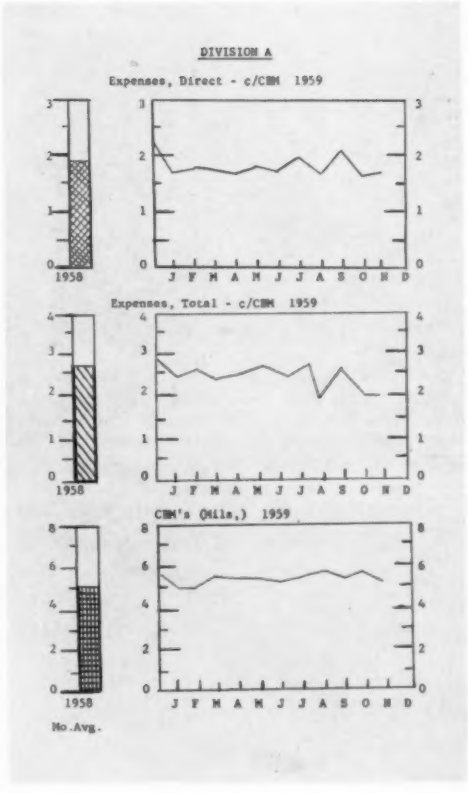
Company B

DIVISION A - TRUNK EXPENSES
(000'S OF $)

	1958	1959 Budget (Revised 7/1/59)	Actual Projected For 1959	Jan.	Feb.	Mar.	Nov.	1959 Yr. To Date
Maintenance								
Labor								
Other								
Total Maintenance								
Operating								
Superintendence								
Labor								
Power and Fuel								
Oil Shortages								
Other								
Total Operating								
Total Direct Expenses								
Direct ¢/CBM								
Indirect								
Depreciation								
Benefit Plans								
Property Taxes								
Administrative								
Other								
Total Indirect Expenses								
Total Expenses								
Total ¢/CBM								
CBM's (000's)								

This is a report which is prepared for a division, which happens to be the responsibility center in this case. It is made up on a continuing basis each month for the twelve months of the year. Looking across the top of the sheet, you will note that this statement carries comparable total figures for the prior year, current year's budget as revised at mid-year, actual projection for 1959, charges per month, and year-to-date costs for the current year. Moving down the left side of the report, you will see that maintenance is separated from controllable operating expense and a sub-total of direct expense is set out, then direct costs in cents per hundred-barrel-miles. This is followed by indirect expenses, sub-total, total expenses, and total in cents per hundred-barrel-miles. The last series of numbers represent hundred-barrel-miles in thousands.

This exhibit shows the type of supporting chart sheet which is attached to the statement shown above. These three charts indicate, a) controllable expenses by month, b) total expenses by month, and 3) hundred barrel-miles per month for the current year. The graphs to the left show the average of these three for the prior year.

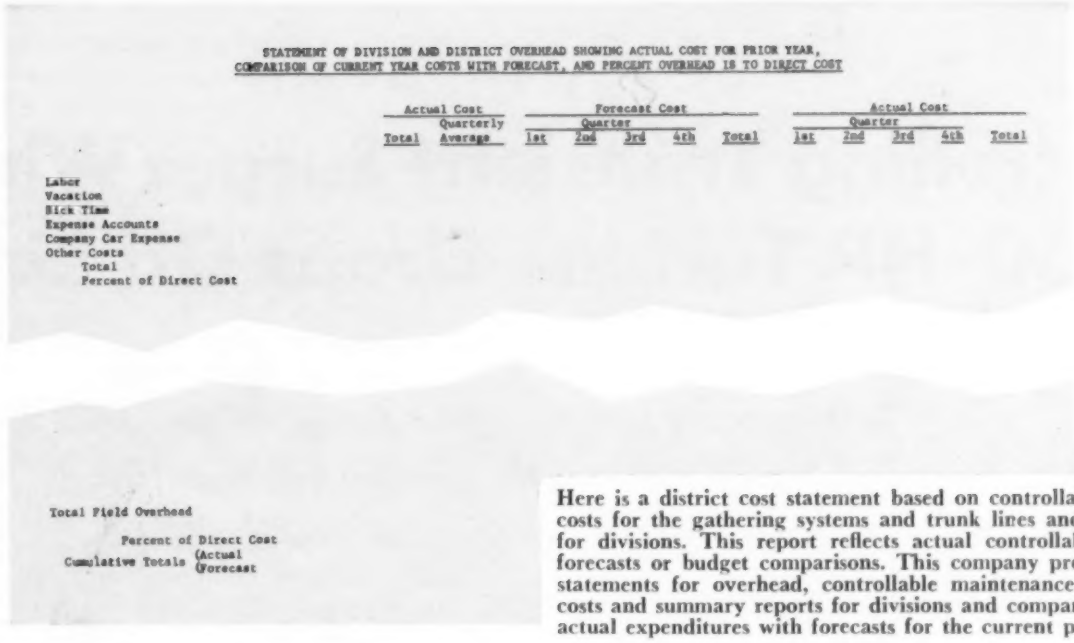

DIVISION A
Expenses, Direct - ¢/CBM 1959
1958
J F M A M J J A S O N D
Expenses, Total - ¢/CBM 1959
1958
J F M A M J J A S O N D
CBM's (Mils.) 1959
1958
Mo.Avg.
J F M A M J J A S O N D

This represents the summary of net income before taxes. The report is separated between trunk line and gathering operations. Volumes for the former are reflected as hundred barrel-miles in thousands and for the latter as barrels handled in thousands. The four revenue columns show prior year, year to date for current year, current month for prior year, and current month for the year in progress. The next four columns to the right accumulate expenses under the same captions as are used to reflect revenue. The four columns to the far right reflect net income before taxes in thousands for prior year, current year to date, current month of prior year, and current month under review.

SUMMARY OF NET INCOME BEFORE TAXES

	VOLUMES				REVENUE (000'S OF $)				EXPENSES (000's OF $)				NET INCOME BEFORE TAXES (000's OF $)			
	1958	1959 Yr.To Date	Nov. 1958	Nov. 1959	1958	1959 Yr.To Date	Nov. 1958	Nov. 1959	1958	1959 Yr.To Date	Nov. 1958	Nov. 1959	1958	1959 Yr.To Date	Nov. 1958	Nov. 1959
TRUNK																
Division A																
Division B																
Division C																
Total																
GATHERING																
Division A																
Division B																
Division C																
Total																

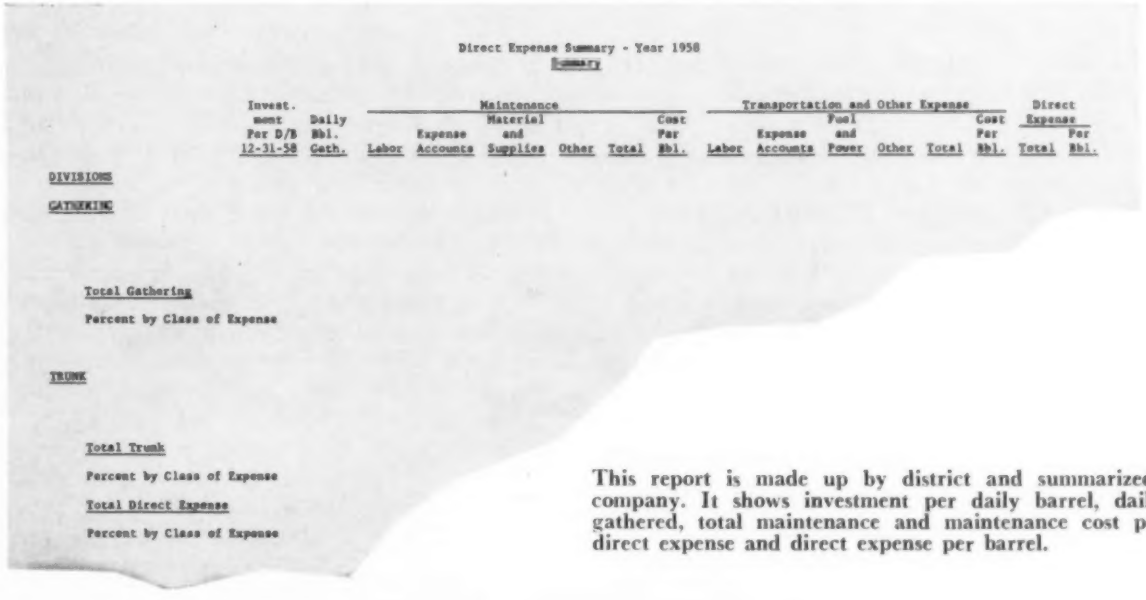
Company C



STATEMENT OF DIVISION AND DISTRICT OVERHEAD SHOWING ACTUAL COST FOR PRIOR YEAR, COMPARISON OF CURRENT YEAR COSTS WITH FORECAST, AND PERCENT OVERHEAD IS TO DIRECT COST

	Actual Cost		Forecast Cost					Actual Cost				
		Quarterly	Quarter					Quarter				
	Total	Average	1st	2nd	3rd	4th	Total	1st	2nd	3rd	4th	Total
Labor												
Vacation												
Sick Time												
Expense Accounts												
Company Car Expense												
Other Costs												
Total												
Percent of Direct Cost												
Total Field Overhead												
Percent of Direct Cost												
Cumulative Totals (Actual												
Cumulative Totals (Forecast												

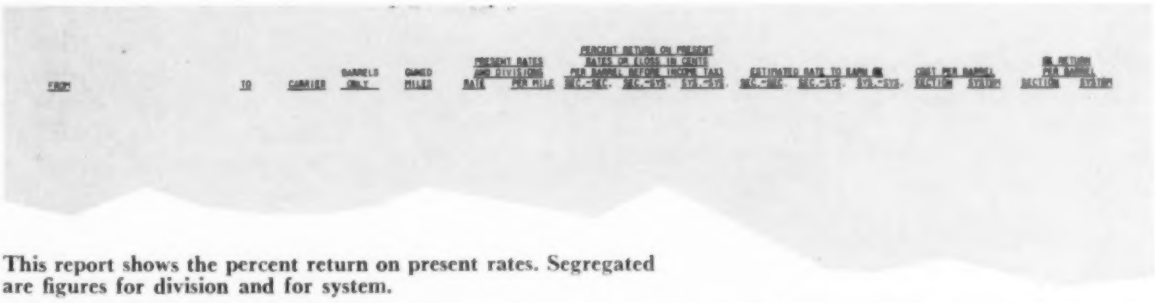
Here is a district cost statement based on controllable operating costs for the gathering systems and trunk lines and summarized for divisions. This report reflects actual controllable costs and forecasts or budget comparisons. This company prepares similar statements for overhead, controllable maintenance, controllable costs and summary reports for divisions and company comparing actual expenditures with forecasts for the current period.



Direct Expense Summary - Year 1958
Summary

	Invest. ment Per D/B 12-31-58	Daily Bbl. Gath.	Maintenance						Transportation and Other Expense						Direct Expense	
			Labor	Expense Accounts	Material and Supplies	Other	Total	Cost Per Bbl.	Labor	Expense Accounts	Fuel and Power	Other	Total	Cost Per Bbl.	Total	Per Bbl.
DIVISIONS																
GATHERING																
Total Gathering																
Percent by Class of Expense																
TRUNK																
Total Trunk																
Percent by Class of Expense																
Total Direct Expense																
Percent by Class of Expense																

This report is made up by district and summarized for the company. It shows investment per daily barrel, daily barrels gathered, total maintenance and maintenance cost per barrel; direct expense and direct expense per barrel.



FROM	TO	CARRIER	BARRELS ONLY	OWNED MILES	PRESENT RATES AND DIVISIONS RATE	PRESENT RATES AND DIVISIONS PER MILE	PERCENT RETURN ON PRESENT RATES OR LOSS IN CENTS PER BARREL BEFORE INCOME TAXES SEC-DIV.	SEC-SYS.	SYS-SYS.	ESTIMATED RATE TO EARN 8% SEC-DIV.	SEC-SYS.	SYS-SYS.	COST PER BARREL SECTION	SYSTEM	8% RETURN PER BARREL SECTION	SYSTEM

This report shows the percent return on present rates. Segregated are figures for division and for system.

These are minimum examples of what accountants have done so far to measure operating performance on the basis of responsibility centers such as district or division.

It seems fair to conclude that pipe line accountants are aware of the advantages of responsibility accounting and are trying to develop useful controls and reports for operating management. It is recognized that if accountants don't provide this control data, the problem will be shifted to the operating departments; a corollary to this is that good responsibility accounting leads to less staff work in operations. It is a commendable desire to get better accountability, and, by working together and sharing the development of the responsibility concept, transportation accounting and operating management can achieve this goal.

ACKNOWLEDGMENT

From three papers presented at the Annual Pipe Line Conference of the American Petroleum Institute's Division of Transportation, Mayo Hotel, Tulsa, April 28-29, 1960.

AN API FEATURE

Controlling Transient Surges When 5,000-HP Turbine Drops Off Line

In a liquid-carrying line, the sudden rise in suction pressure sends a high-pressure wave traveling upstream. Here is the solution Tapline worked out to protect piping in critical areas

By R. R. Burnett, Assistant Chief Engineer - Pipe Line
Trans-Arabian Pipe Line Co., Beirut, Lebanon

The addition of 5,000 horsepower intermediate gas turbine pumping units to the Trans-Arabian 754 mile, crude oil pipe line was completed near the end of 1957.[1] One of these units was installed approximately midway in each of the four original pipe line sections. Each unit is designed for remote operation by VHF radio link from the next upstream pump station and is automatically tripped off should any one of several unsafe conditions actuate a protective shutdown device.[2]

Referring to the map in Fig 1, Tapline's original system consisted of the 30-31 inch pipe line, four pump stations in Saudi Arabia and the marine terminal near Sidon, Lebanon. Each pump station was provided with a 96,000 barrel floating-roof tank which is open to the pump station incoming stream and prevents the generation of high pressure surges if a station is unexpectedly shut down. Thus, in a hydraulic sense, each of the four sections is a separate pipe line.

An intermediate gas turbine-driven pump was installed without a tank, at approximately the mid-point of each of the four sections. Whenever one of these units is tripped off by a safety device, the pump suction pressure rises rapidly and initiates a high-pressure surge which travels back upstream to the next pump station.

The pipe line has a tapered wall thickness—that is, the thicker pipe wall is installed on the discharge side of the pump stations, where the normal pressures are high, while the thinner wall is in regions of normally low pressure such as those immediately upstream from the gas turbine units. These latter regions are subjected to the highest surge pressure. At points where the wall thickness changes, the situation is usually the most critical because the initial gradient pressure is relatively high in relation to the maximum allowable pressure, leaving less available to take the surge. In several cases, these points would be over-stressed unless measures were taken to control the surge pressures.

FIGURE 1—THE TRANS-ARABIAN PIPE LINE SYSTEM. The intermediate 5,000-hp gas-fired turbine stations were installed at mid-points of the four sections of line. Because the original line was laid of 30 and 31-inch pipe, there are some critical areas where a heavy transient pressure wave could cause rupture. Dropping off one of the turbines can initiate such a wave traveling from the suction upstream toward the next station. To prevent the surge from damaging the 31-inch pipe, Tapline starts a rarefaction wave which meets the pressure wave at about mid-point between the stations.

The simplest control method would be to lower the normal operating pressures to allow for surges. But this method would reduce the pipe line throughput; and it was calculated that approximately 40,000 BPD of

throughput would be lost unless other effective surge protective systems could be devised.

DESIGN FEATURES

Transient Pressure Studies. With this incentive, a detailed study of available transient pressure theory was made. The definitive work on the subject is by Ludwig and Johnson,[8] who developed the theory for sudden change of flow, and attenuation of the resulting traveling pressure wave in a long pipe line. It was assumed that, when a pumping unit tripped off, its suction pressure would rise suddenly until either of two things happened:

1. With a relatively small initial differential pressure across the pump, the rise in suction pressure would be arrested when it equalized with the falling discharge pressure and flow would then be resumed through the check valve which bypasses the pump; or
2. With higher differential pressure, the suction pressure would rise until flow stopped, after which a more gradual rise would continue until equalization of suction and discharge pressures occurred.

In either case, a pressure surge would travel upstream at acoustic velocity, diminishing in magnitude as it progressed. Each pumping unit was provided with a check valve in series with the pump, so the possibility of flow reversal was discarded. The analysis, an example of which is shown in Figure 2, assumed that:

1. The pressure equalized at the intermediate turbine unit approximately midway between the initial suction and discharge pressure, and,
2. The maximum pressures reached along the line could be approximated by drawing a straight line from the midway pressure at the intermediate unit to a point somewhat above the initial upstream station pressure. This line was approximated by using Ludwig's curves for pressure distribution in the wake of the traveling wave front and modifying them to take into account the flow through intermediate turbine location.

Subsequent tests revealed that pressure equalized at a level significantly below midway at the turbine unit, but after making this correction, the straight line described above was a conservative first-approximation to the actual pressure build-up in upstream regions.

Rarefaction Wave to Partially Cancel Pressure Wave. These detailed calculations were made with the thought that protection against overpressuring the critical areas might be achieved by rapidly reducing the upstream pump station pressure, transmitting a rarefaction wave to intercept and subtract from the oncoming high-pressure surge.

The analysis led to classifying the critical regions of the pipe line as shown in Figure 2. The lines marked, "33 sec.," "56 sec." etc., show the predicted progress of an uncontrolled pressure surge after tripping off the unit. All three of the critical regions A, B, and C, would be overpressured. These representative regions were considered individually as follows:

► **Region A**—This is the control point at which pipe wall thickness changes and limits normal operating pressure. Since this is near the upstream station, it is evident that a rarefaction wave initiated by quickly reducing the station pressure would reach this region to protect it before the high-pressure surge would arrive from the gas turbine unit.

► **Region B**—This is a critical point of wall thickness

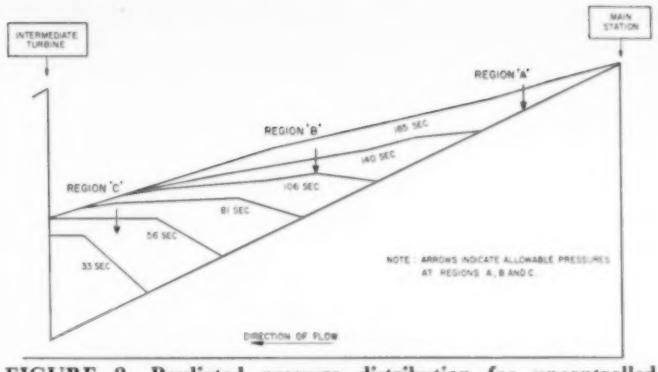


FIGURE 2—Predicted pressure distribution for uncontrolled surges when the turbine unit trips off. Flow is from right to left.

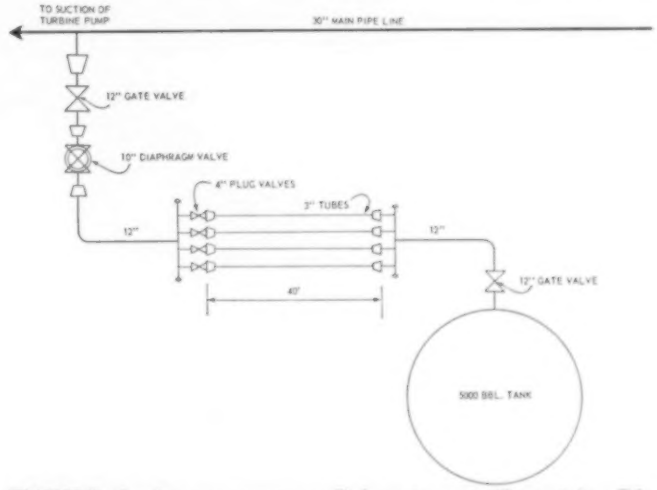


FIGURE 3—Surge pressure relief system at Qaryatain. Diaphragm valve opens when turbine drops off line and allows pressure to bleed through tubes into 5,000-barrel tank. This helps.

change, located somewhat nearer to the intermediate pumping unit than to the upstream station. In this example, 106 seconds would elapse before the pressure would exceed the allowed limit. It was decided, subject to final tests, that this region could also be protected by reducing upstream station pressure.

Tone Signals Actuate Pressure Reduction. Regions of the A and B types occur in all four sections on Tapline, so systems were designed to accomplish rapid base station pressure reduction whenever a gas turbine unit trips off. This feature is provided by transmitting a continuous tone over the VHF communications system from the gas turbine unit to the upstream station so long as the gas turbine unit is in operation.

The tone is used to hold open a relay in three of the six diesel engine shut-down circuits at Qaisumah, Rafha, Badanah and a shift in frequency of the tone shuts down the three units. At Turaif, which is powered by two 5,000 hp gas turbine pumping units, a frequency shift in the tone from Qaryatain reduces the two Turaif units to idle speed, thus decreasing Turaif's outbound pressure.

► **Region C**—Excessively high pressures would build up here within approximately 35 to 40 seconds. A rarefaction wave from the upstream station would be unable to reach this region soon enough for protection. It was decided that a relief valve could be installed on the suction side of the pumping unit to limit the pressure rise. Fortunately, a region of this type exists only in the Turaif-Qaryatain section, so a relief valve was installed only at Qaryatain.

The relief system is shown in Figure 3 and consists

functionally of the relief valve, four 3" pressure reducing tubes and a 5,000-barrel receiving tank. The relief valve is a 10-inch control valve arranged so that air pressure on the diaphragm operator opens the valve. An air supply tank and controls are located near the valve and function in the following manner:

1. When the pumping unit trips off, the air tank pressure is applied directly to the valve diaphragm operator for fast opening.
2. After the valve is opened, air to the diaphragm is controlled by a pressure controller set to hold 300 psi on the main pipe line.
3. After a preset time interval, the air is bled off the diaphragm at a controlled rate until the valve is closed.

The entire cycle returns the valve to the closed position 6 to 7 minutes after the turbine unit is tripped off. This time allows for the effect of Turaif's pressure reduction to be transmitted through Qaryatain and for some degree of pressure stabilization to take place throughout the pipe line. In designing this system, it was hoped that the valve could be opened at nearly an optimum rate which would allow Qaryatain's suction pressure to rise smoothly to approximately 300 psi. This was desirable since the rise in pressure is accomplished by a reduction of flow in the incoming stream. Allowing the pressure to rise to the maximum safe value (determined by the allowable surge at upstream Region C) effectively minimizes the volume of relief flow through this valve. Figure 4 gives the test pressures and valve position versus time after tripping off the Qaryatain pumping unit.

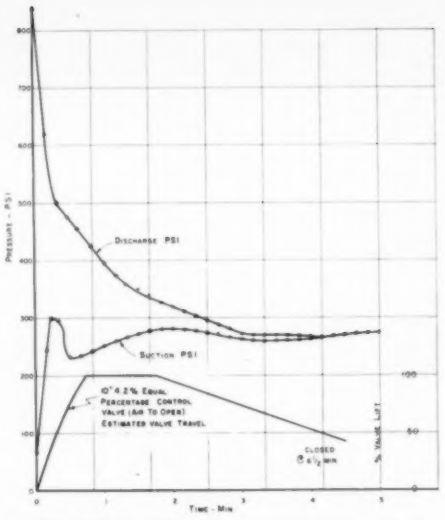


FIGURE 4—Qaryatain pressures and relief valve position after tripping off turbine unit.

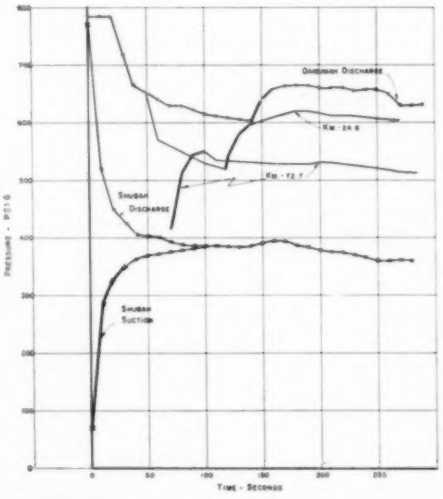


FIGURE 5—Surge pressure after Shubah turbine unit trips off.

Testing the Installed Facilities. After completing the installations, extensive surge pressure tests were required to check the feasibility of the designed surge protection systems and to make final adjustments.

Testing techniques were simple and common to all the tests. Transient pressures versus time were obtained at each critical location by installing a tested laboratory-type bourdon tube pressure gage. Readings were recorded by an observer at 10-second intervals.

For each of the four pipe line sections, the test procedure which was used to determine the effectiveness of the upstream pressure reduction was as follows:

1. Three gas turbine shut-downs were made with the upstream station pressure held constant so that the deterioration of the high-pressure wave front and pressure distribution in its wake could be clearly observed. Initial pumping unit differential pressure was increased in each successive test with the hope that results could be extrapolated to maximum conditions.
2. At least one test of the effect of reducing base station pressure was run, recording wave behavior as it traveled downstream. The gas turbine unit was off stream for this test.
3. One or more tests were made, tripping off the gas turbine unit and automatically reducing the upstream station pressure.

Figure 5 shows pressure readings for one of the composite test runs. An unusual requirement of this particular test was to determine the magnitude of the pressure wave front at km 72.7 after the Shubah gas turbine unit was tripped off, under a condition of high differential pressure. If the automatic pressure reduction system at Qaisumah were allowed to operate normally, the rarefaction wave would have met the oncoming wave from Shubah at approximately km 70, so that measurements at km 72.7 would be difficult to interpret. On the other hand, the surge from Shubah, if not limited, would eventually over-pressure the region of km 72.7.

Therefore, the procedure was to start with a somewhat lower initial pressure and to delay manually the Qaisumah pressure reduction for 20 seconds, which allowed the full wave front to pass through km 72.7 before it was intercepted by the rarefaction wave. At normal pressures, the surge must be interrupted within ten seconds after it reaches km 72.7. Thus, Qaisumah pressure must be reduced with no appreciable delay. This test demonstrates the elements of testing technique used for the entire series.

Interpretation of Experimental Data. In the earlier stages of testing, data were obtained under a variety of initial conditions, generally with operating pressures reducing to insure safety to the pipe line. This required that the data be analyzed and extrapolated to predict results over the full range of operating conditions.

The problem of analysis was intensified because in areas of the Region B type, the rarefaction wave meets the oncoming surge wave front at the critical locations on the pipe line, as shown in Figure 6. Both the high pressure wave traveling upstream and the rarefaction wave traveling downstream must be thought of as "extended" wave fronts which cover a distance of 15 to 20 miles each. The region where the two fronts meet is thus 30 to 40 miles in length. Any critical point located in the downstream half of this region is subjected first to a pressure rise, then a pressure decrease. The initial rise is due to a fraction of the high pressure front moving upstream. The time interval involved in the initial pressure rise can be readily computed because the velocity of travel of the fronts can be accurately measured. But the magnitude of the pressure rise depends upon the attenuation of a fraction of the wave front.

Wave front attenuation, in turn, has been found to be a function not only of the magnitude of pressure rise at the intermediate pumping unit but also rate of this pressure change, or the time during which the change takes place. This last fact presented a difficulty because Ludwig's analytical method for computing attenuation assumes that an instantaneous pressure change occurs at the wave front and does not provide for handling a more or less gradual pressure rise within the front. Another aspect of the problem is that the pipe line under present study is operated at higher stresses than those used in the Code for Pressure Piping, ASA B-31.4-1959. This fact adds emphasis to the need for accuracy in the method of calculating pressure wave attenuation.

For these reasons an extension of the mathematical development was undertaken to compute wave front attenuation for the general cases arising from gradual pressure change. The solution must satisfy the basic partial differential equations for turbulent flow, which may be written in terms of dimensionless variables as follows:

$$\pm\frac{\partial P}{\partial X} = V^n + \frac{\partial V}{\partial T} \qquad 1.$$

$$\pm\frac{\partial P}{\partial T} = \frac{\partial V}{\partial X} \qquad 2.$$

in which the plus sign is used if distance ratio, X, is measured positively in the direction opposite to flow and the minus sign is used if X is positive in the direction of flow. The dimensionless ratios are equal to those defined by Ludwig. Each is proportional to a true variable, i.e., P for pressure, V for velocity, T for time, and X for distance along the pipe line.

Pressure can be eliminated from Equations 1 and 2 by taking the second mixed partial derivative of P with respect to X and T in each equation. The resulting velocity equation is:

$$\frac{\partial^2 V}{\partial X^2} = nV^{n-1}\frac{\partial V}{\partial T} + \frac{\partial^2 V}{\partial T^2} \qquad 3.$$

In Equation 1, if the term $\frac{\partial V}{\partial T}$ were omitted, the remaining equation would represent the friction loss in a pipe line, with pressure loss per unit length of pipe being proportional to the *n*th power of the flow rate, represented by V^n. The exponent, n, is usually taken as two, although this is somewhat in error for most practical pipe line systems, in which the exponent can be as low as approximately 1.70. This is a refinement which will be considered later. For this present case, the exponent will be taken as 2.0 because the mathematics is simplified.

It can be shown that a steady-state flow condition is described in the dimensionless ratios by the relations:

$$V = 1$$

$$P = X + P_o$$

where P_o is the dimensionless ratio for the initial steady pressure at the downstream end of the line, at which $X = 0$. Of course, differences in pipe line elevation must be converted to dimensionless pressure and added or subtracted to the above relation for P to obtain corrected values.

The solution will be handled in two parts: numerical and analytical.

• The numerical solution offers possibilities for solving any problem in either increasing or reducing turbulent flow, including the attenuation of traveling wave fronts and pressure distribution in the pipe line system in the region in the wake of a wave front. However, because of the labor involved, the numerical solution outlined in Appendix III has been computed manually only as far as necessary for the case of reducing turbulent flow and with $n = 2$.

The numerical method used here can be used with a reasonable amount of labor to solve manually any specific case desired and it could be readily applied on a digital computer to solve all practical cases of increasing or decreasing flow in dimensionless terms applicable to any pipe line problem.

For the present problem of reducing turbulent flow, Figure 8 shows graphically the result of the numerical solution. At $X = 0$, the pressure is changed with time along one of the solid lines in the graph, or along any interpolated line. The dashed lines indicate the velocities encountered during the pressure change. The entire solution is based upon flow rates being reduced at uniform rates, or V changes linearly with time. These P - V - T relations apply to any fixed location on the pipe line. The numerical solution has been carried only far enough to obtain Figure 8, but in this computation it was necessary to find values of P and V over a considerable distance, X, which thus gives pressure and velocity distribution curves in this region. Figure 7 shows these curves for the case in which turbulent flow is stopped in time $T_{so} = 2.0$. In an unpublished paper, Krahula[4] obtained essentially identical results as shown in Figure 8 by use of an entirely different numerical method.

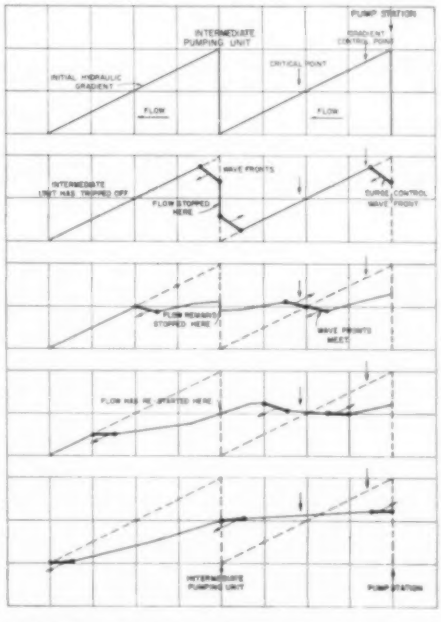


FIGURE 6—Approximate pressure distribution with surge control at progressive time intervals after intermediate pumping unit trips off. Note that flow is from right to left. When the unit trips, the check valve stops all flow until upstream pressure rises as shown in fourth panel from top. Note that the surge control wave front intercepts the wave about mid-point between stations.

• The second part of the solution is analytical. For turbulent flow, Equations 1 and 3 are non-linear and an analytical solution is not necessarily available. However, one set of solutions has been found by using trial functions and these give the attenuation of extended traveling wave fronts. As mentioned, the numerical solution could also be carried out for attenuation of traveling wave fronts. However, the analytical solutions give this with considerably less effort, subject to their limitations, which will be discussed later.

The derivation is started by assuming that transient component of pressure change is linearly proportional to

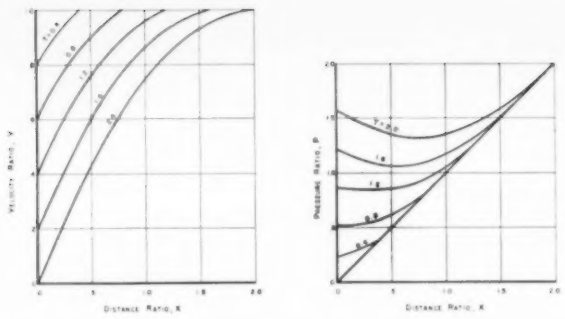


FIGURE 7—Numerical solution for velocities and pressures versus distance. Turbulent flow is stopped at a uniform rate in time; $T_{so} = 2.0$ at $X = 0$.

velocity change at the point of observation. In other words, an observer traveling at acoustic velocity and situated at any point within a traveling wave front would "see" a transient component of pressure change and a velocity change linearly proportional to each other. This assumption is given by the relation:

$$P = A(1—V) + X + P_o \qquad 4.$$

The term, $A(1—V)$, is the transient component of pressure, later called P_s. The constant, A, is unity for a case of instantaneous pressure change. But for a gradual change, A is greater than unity.

From Equation 4, the partial derivatives of P with respect to X and T are written:

$$\frac{\partial P}{\partial X} = —A\frac{\partial V}{\partial X} + 1 \quad . \quad \frac{\partial P}{\partial T} = —A\frac{\partial V}{\partial T}$$

These are substituted into Equations 1 and 2 to eliminate P as well as either T or X. The two results are:

$$\frac{\partial V}{\partial X} = \left(\frac{—A}{A^2 — 1}\right)(V^2 — 1) \qquad 5.$$

$$\frac{\partial V}{\partial T} = \left(\frac{1}{A^2 — 1}\right)(V^2 — 1) \qquad 6.$$

Integrating Equation 5 gives V as a function of X plus an arbitrary function of T and the constant of integration. The function of T is found by integrating Equation 6, and the combined result is:

$$V = \tanh\left[\frac{AX — T}{A^2 — 1} + C\right] \qquad 7.$$

Equation 7 is a solution to the simultaneous Equation 1 and 2 for turbulent flow and it is also a solution to Equation 3.

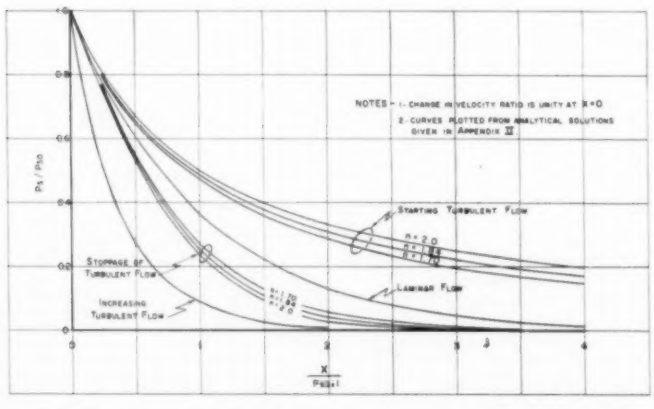

NOTES: 1- CHANGE IN VELOCITY RATIO IS UNITY AT X=0
2- CURVES PLOTTED FROM ANALYTICAL SOLUTIONS GIVEN IN APPENDIX II
STARTING TURBULENT FLOW
STOPPAGE OF TURBULENT FLOW
INCREASING TURBULENT FLOW
LAMINAR FLOW

FIGURE 9—Attenuation of maximum wave front pressures after starting or stoppage of flow.

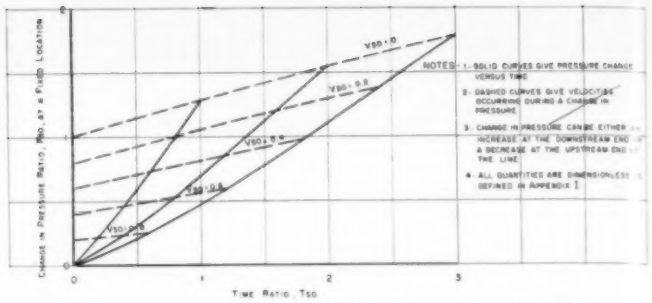

NOTES: 1- SOLID CURVES GIVE PRESSURE CHANGE VERSUS TIME
2- DASHED CURVES GIVE VELOCITIES OCCURRING DURING A CHANGE IN PRESSURE
3- CHANGE IN PRESSURE CAN BE EITHER AN INCREASE AT THE DOWNSTREAM END OR A DECREASE AT THE UPSTREAM END OF THE LINE
4- ALL QUANTITIES ARE DIMENSIONLESS AS DEFINED IN APPENDIX I

FIGURE 8—Pressure-Time-Velocity relations. Numerical solution for decreasing turbulent flow.

The solution, Equation 7, is limited in usefulness because it is necessary for the argument of the hyperbolic tangent to approach infinity in order for V to become unity, its initial value. However, the solution does meet boundary conditions needed in finding the attenuation of traveling wave fronts. In the latter case, an observer who starts from the end of the pipe line and travels at acoustic velocity with the wave front would observe a velocity ratio of $V = V_{so}$, less than unity at $X = 0$ and would "see" V approach unity as X approaches infinity. Also, if the surge pressure is linearly proportional to the change in velocity as given in Equation 4, then the observer would "see" an initial surge pressure of say $P_s = P_{so}$ at $X = 0$; and then traveling with the wave front he would observe P approach the initial gradient, $P = X + P_o$ as X approaches infinity. The foregoing statements can be summed up mathematically as boundary conditions:

$$\text{at } T = T_{so} \text{ and } X = 0;\ V = V_{so},\ P = P_{so} + P_o$$

$$\text{at } T = X + T_{so},\ V = V_s,\ P = P_s + X + P_o$$

These conditions inserted into Equation 7 give the particular solution:

$$V_s = \tanh\left[\frac{X(1 — V_{so})}{P_{so} + 1 — V_{so}} + \tanh^{-1}V_{so}\right] \qquad 8.$$

And from Equation 4, the transient component of P will be called P_s:

$$P_s = \frac{P_{so}}{1 — V_{so}}\left[1 — \tanh\left(\frac{X(1 — V_{so})}{P_{so} + 1 — V_{so}} + \tanh^{-1}V_{so}\right)\right] \qquad 9.$$

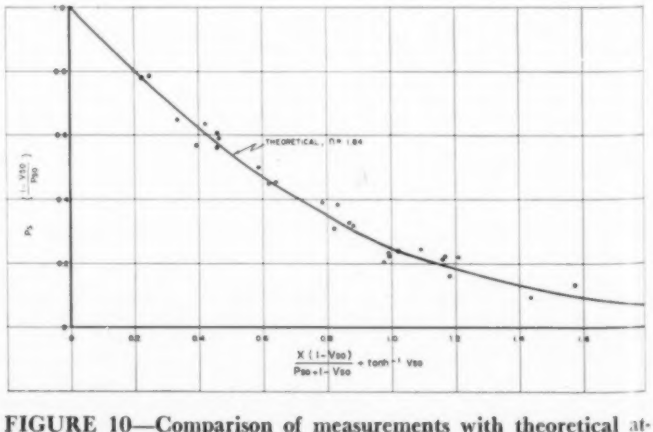


FIGURE 10—Comparison of measurements with theoretical attenuation of surge pressures in traveling waves for reduction of turbulent flow after shutdown of 5,000 hp pumping unit.

to which the initial gradient $P = X + P_o$ must be added to obtain the total value of P at the wave front.

In case the flow is completely stopped at $X = 0$, so that $V_{so} = 0$; the maximum surge pressure at the peak of the traveling wave front is:

$$P_s = P_{so}\left[1 - \tanh\left(\frac{X \cdot}{P_{so} + 1}\right)\right] \qquad 10.$$

This equation is plotted as one of the curves of Figure 9, which is presented principally to show a comparison of the wave front attenuation for the various cases.

In Equations 8 and 9, the values V_{so} and P_{so} are those reached at the starting point of the wave front, $X = 0$, after an interval of time $T = T_{so}$, during which the initial pressure change has taken place.

The combined numerical and analytical solutions for reducing turbulent flow can be used for either a case of raising pressure at the downstream end of the line or one of lowering the upstream pressure, either of which would reduce flow rate. Thus in Figure 8 and Equations 8, 9, and 10, P_{so} can be regarded as change in pressure in a way to reduce the flow and P_s is the transient component of pressure in the wave front which can be traveling upstream and above the initial gradient or a wave traveling downstream below the gradient. However, since the problem is non-linear, the principal of superposition cannot be applied. This means that the initial gradient, in this problem, is an essential part of the solution. The cases of increasing turbulent flow, starting from either a static or a flowing condition, are thus entirely separate problems and must be solved independently.

The laminar flow problem, on the other hand, is linear because the frictional resistance to flow is proportional to the first power of velocity in Equation 1. Thus the transient components of P and V can be isolated to generate a solution; then an initial gradient can be added into the final result if a gradient exists.

Appendix II and Figure 9 summarise the analytical solutions obtained for laminar flow and for increasing or decreasing turbulent flow.

With these solutions in hand, the procedure for correlating experimental data has made use of the numerical solution at $X = 0$ to determine the surge velocity, V_{so} from Figure 8, corresponding to the measured value of P_{so} and a known value of X for remote location to substitute in Equation 9 and find the surge pressure P_s at the remote point.

A refinement in Equation 9 for wave front attenuation was made to correct for the fact that fluid friction in a large diameter pipe line is not exactly proportional to the square of velocity. For the 30-31 inch pipe line on which this report is based, a representative value of the exponent is n = 1.84, and this is the curve actually being used for prediction of surges under all conditions. The use of this type of curve has the advantage of permitting direct comparison with the test data for all the various conditions and locations. This is illustrated in Figure 10 on which is plotted pressure wave attenuation from 17 separate surge tests conducted on the four sections of the Trans-Arabian pipeline. Appendix IV gives a numerical example of the use of Figures 8 and 10 to find wave front attenuation.

A somewhat better physical comparison of attenuation rates is shown in Figure 11, giving surge pressure ratio versus distance for various values of T_{so}, the time taken to stop flow at $X = 0$. These curves can be used directly only if flow is stopped at $X = 0$. This shows that attenuation is less rapid for larger values of T_{so}.

Figure 12 gives results of a few tests in which turbulent flow was stopped by slowly reducing the discharge pressure at a pump station. During the tests, the exponent, n, would start from approximately a value of 1.84, then reduce to 1.70 and eventually 1.0 (laminar) just before complete stoppage. Test results appear to correlate reasonably well with numerical solutions for pressure change required to stop the flow in various time intervals, with n = 1.0, 1.84 and 2.0.

The bulk modulus used in the analysis is that given for Mixed West Texas and New Mexico Crude in Section III of the "Final Report of Joint Surge Conference."[5] This was done because a number of checks on wave travel velocity in the pipe line gave apparent bulk modulus values, using mean pressure, which correlated satisfactorily with those referred to above.

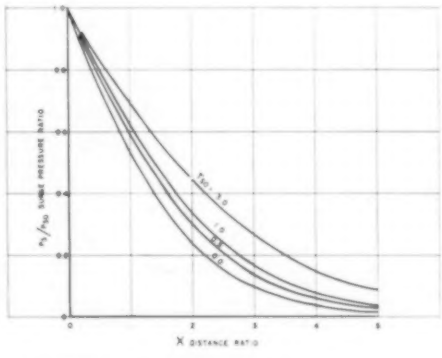


FIGURE 11—Comparison of surge attenuation for extended wave fronts after flow stoppage.

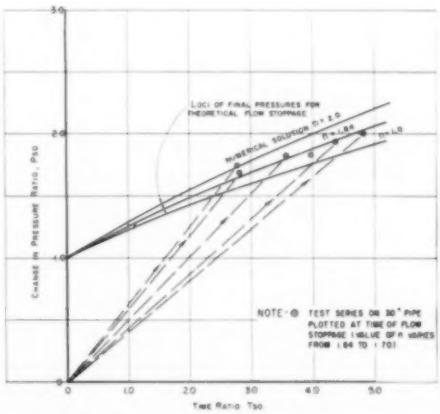


FIGURE 12—P-V-T Relations Comparison of theoretical and experimental results for gradual flow stoppage.

CONCLUSIONS

1. Control of surge pressure by automatically reducing upstream pressure proved to be generally satisfactory in the application described. This method requires detailed analysis of surge pressures. Also it is feasible only if a dependable communications system is installed.

2. The analytical solution for wave front attenuation has been used successfully. However, comparison with data and with the numerical solution indicates that the assumed linear pressure-velocity relation in the wave front is only approximately correct and its error becomes more significant for slower rates of pressure change.

3. The numerical solution, developed mainly for pressure-velocity-time relations at a fixed location, offers a means for solving a wide range of transient flow problems with a reasonable amount of effort.

4. In designing a new pipe line system, significant economy can be gained in many cases by advance analysis of transient pressure distribution.

5. The analysis of pressure-velocity-time relations may be useful in predicting the transient performance of control valves and pumps and the response of pump station control systems.

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[2] "A Thin-Route Beyond-The-Horizon VHF System in the Middle East," by J. D. Hoffman. 5th National Communications Symposium, Utica, New York, October, 1959.
[3] "Prediction of Surge Pressures in Long Oil Transmission Lines," Milton Ludwig and S. P. Johnson, API Annual Meeting, November 14, 1950. Also ASME Paper No. 50-SA-26 presented by Milton Ludwig in June, 1950.
[4] "Analysis of Pressure Surges in Long Pipe Lines Due to Gradual Stoppage of Flow," J. L. Krahula, submitted to the Department of Theoretical and Applied Mechanics, College of Engineering, University of Illinois, Urbana, Illinois, 1952.
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[6] *Numerical Methods in Engineering*, by M. G. Salvadori and M. L. Baron, Prentice-Hall, Inc., New York, 1952.

ACKNOWLEDGMENT

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APPENDIX I

Definitions of terms and dimensionless ratios:

$P = pg/a\rho v'$
$V = v/v'$
$T = tp'g/v'\rho$
$X = xp'g/a\rho v'$
t = time, seconds, sec.
p = pressure, pounds per square foot, psf
v = velocity of flow, feet per second, ft/sec
x = distance, feet, ft
g = acceleration of gravity, ft/sec^2
p' = initial pressure gradient, psf/ft
v' = inital liquid velocity, ft/sec
ρ = liquid density, lb/ft^3
a = acoustic velocity, ft/sec
K_e = effective bulk modulus of liquid and pipe, lb/ft^2
k = bulk modulus of liquid, lb/ft^2
d = pipe diameter, ft
h = pipe wall thickness, ft
E = modulus of elasticity for pipe material, lb/ft^2
γ = Poisson's ratio for pipe material (0.30 for steel)

Acoustic Velocity, $a = \sqrt{\dfrac{K_e g}{\rho}}$

For a pipe line restrained axially, $K_e = \dfrac{k}{1 + \dfrac{kd}{Eh}(1 - \gamma^2)}$

T_{so}—Time ratio defining the time during which pressure and flow are changed to establish the wave front at a given location such as $X = 0$.

P_{so}—Pressure ratio defining the pressure change taking place at the location, such as $X = 0$, where the wave front is generated in time $T = T_{so}$.
(For a reduction in flow rate, P_{so} represents either an increase in pressure at the downstream end of the line or a pressure decrease at the upstream end.)

P_s—Transient component of pressure in the wave front at any location.

V_{so}—Final velocity ratio reached when $T = T_{so}$ and $P = P_{so}$ at the end of the line where the wave front is generated. V_s is velocity reached in wave front at any location.

Basic Partial Differential Equations of unsteady flow are as follows:

$$\pm \frac{\partial p}{\partial x} = \frac{p'}{(v')^n} v^n + \frac{\rho}{g}\frac{\partial v}{\partial t} \qquad \pm \frac{\partial p}{\partial t} = \frac{\partial v}{\partial x}$$

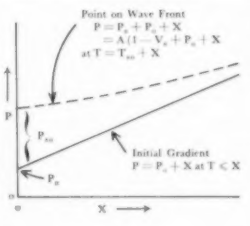
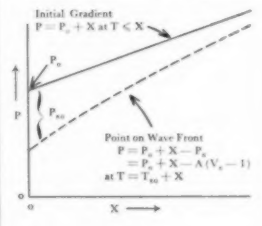
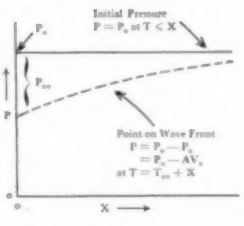
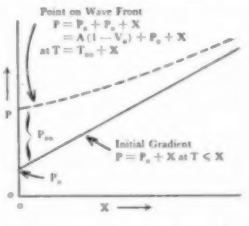
The quantities p' and v' are both constants which combined to form the coefficient of fluid friction in the more familiar equation for steady flow:

$$\frac{p}{x} = \frac{p'}{(v')^n} v^n$$

The value of n in these studies is taken from familiar graphical plots of friction factor versus Reynolds Number for the pipe diameter and range under consideration.

APPENDIX II

ANALYTICAL SOLUTIONS FOR WAVE FRONT ATTENUATION

EXPLANATION OF STEPS	REDUCING TURBULENT FLOW	INCREASING TURBULENT FLOW	STARTING TURBULENT FLOW	REDUCING LAMINAR FLOW
Key Diagrams				
Differential Equations 1.	$\frac{\partial P}{\partial X} = V^n + \frac{\partial V}{\partial T}$	$\frac{\partial P}{\partial X} = V^n + \frac{\partial V}{\partial T}$	$\frac{\partial P}{\partial X} = V^n + \frac{\partial V}{\partial T}$	$\frac{\partial P}{\partial X} = V + \frac{\partial V}{\partial T}$
Differential Equations 2.	$\frac{\partial P}{\partial T} = \frac{\partial V}{\partial X}$	$\frac{\partial P}{\partial T} = \frac{\partial V}{\partial X}$	$\frac{\partial P}{\partial T} = \frac{\partial V}{\partial X}$	$\frac{\partial P}{\partial T} = \frac{\partial V}{\partial X}$
Differential Equations 3.	$\frac{\partial V}{\partial X^2} = nV^{n-1}\frac{\partial V}{\partial T} + \frac{\partial^2 V}{\partial T^2}$	$\frac{\partial V}{\partial X^2} = nV^{n-1}\frac{\partial V}{\partial T} + \frac{\partial^2 V}{\partial T^2}$	$\frac{\partial V}{\partial X^2} = nV^{n-1}\frac{\partial V}{\partial T} + \frac{\partial^2 V}{\partial T^2}$	$\frac{\partial V}{\partial X^2} = \frac{\partial V}{\partial T} + \frac{\partial^2 V}{\partial T^2}$
Assumed Linear Relation of P_s and V 4.	$P = A(1 - V) + P_o + X$	$P = A(V - 1) + P_o + X$	$P = P_o - AV$	$P = A(1 - V) + P_o + X$
Substitution of 4 into 1 and 2 5.	$\frac{\partial V}{\partial X} = \left(\frac{A}{A^2 - 1}\right)(1 - V^n)$	$\frac{\partial V}{\partial X} = \left(\frac{-A}{A^2 - 1}\right)(V^n - 1)$	$\frac{\partial V}{\partial X} = \left(\frac{-A}{A^2 - 1}\right)V^n$	$\frac{\partial V}{\partial X} = \left(\frac{A}{A^2 - 1}\right)(1 - V)$
Substitution of 4 into 1 and 2 6.	$\frac{\partial V}{\partial T} = \left(\frac{-1}{A^2 - 1}\right)(1 - V^n)$	$\frac{\partial V}{\partial T} = \left(\frac{1}{A^2 - 1}\right)(V^n - 1)$	$\frac{\partial V}{\partial T} = \left(\frac{1}{A^2 - 1}\right)V^n$	$\frac{\partial V}{\partial T} = \left(\frac{-1}{A^2 - 1}\right)(1 - V)$
Integration of 5 and 6 7.	$V = \tanh\left(\frac{AX - T}{A^2 - 1} + C\right)$ $n = 2$ $V < 1$	$V = \coth\left(\frac{AX - T}{A^2 - 1} + C\right)$ $n = 2$ $V > 1$	$V = \left[\frac{(1 - n)(T - AX)}{A^2 - 1} + C\right]^{\frac{1}{1-n}}$ $(n \neq 1)$	$V = 1 - e^{\left(\frac{T - AX}{A^2 - 1} + C\right)}$
Substitution for A* and Boundary Conditions 8.	$V_s = \tanh\left[\frac{X(1 - V_{so})}{P_{so} + 1 - V_{so}} + \tanh^{-1}V_{so}\right]$	$V_s = \coth\left[\frac{X(V_{so} - 1)}{P_{so} + V_{so} - 1} + \coth^{-1}V_{so}\right]$	$V_s = \left[\frac{(n-1)V_{so}X}{P_{so} + V_{so}} + V_{so}^{1-n}\right]^{\frac{1}{1-n}}$	$V_s = 1 - (1 - V_{so})e^{\left(\frac{-X(1 - V_{so})}{P_{so} + 1 - V_{so}}\right)}$
P_s from 4 and 8 9.	$P_s = \left(\frac{P_{so}}{1 - V_{so}}\right)\left\{1 - \tanh\left[\frac{X(1 - V_{so})}{P_{so} + 1 - V_{so}} + \tanh^{-1}V_{so}\right]\right\}$	$P_s = \left(\frac{P_{so}}{V_{so} - 1}\right)\left\{\coth\left[\frac{X(V_{so} - 1)}{P_{so} + V_{so} - 1} + \coth^{-1}V_{so}\right] - 1\right\}$	$P_s = \frac{P_{so}}{V_{so}}\left[\frac{(n-1)V_{so}X}{P_{so} + V_{so}} + V_{so}^{1-n}\right]^{\frac{1}{1-n}}$	$P_s = P_{so}e^{\left(\frac{-X(1 - V_{so})}{P_{so} + 1 - V_{so}}\right)}$
P at Any Point on Wave Front 10.	$P = P_s + X + P_o$	$P = -P_s + X + P_o$	$P = -P_s + P_o$	$P = P_s + X + P_o$
For $\Delta V = 1$ at $X = 0$ in 9 11.	$\frac{P_s}{P_{so}} = 1 - \tanh\left(\frac{X}{P_{so} + 1}\right)$	$\frac{P_s}{P_{so}} = \coth\left(\frac{X}{P_{so} + 1} + \coth^{-1}2\right) - 1$	$\frac{P_s}{P_{so}} = \left[\frac{(n-1)X}{P_{so} + 1} + 1\right]^{\frac{1}{1-n}}$	$\frac{P_s}{P_{so}} = e^{\left(\frac{-X}{P_{so} + 1}\right)}$
*	$A = \frac{P_{so}}{1 - V_{so}}$	$A = \frac{P_{so}}{V_{so} - 1}$	$A = \frac{P_{so}}{V_{so}}$	$A = \frac{P_{so}}{1 - V_{so}}$

APPENDIX III

Numerical Solution for Reducing Turbulent Flow[6]

The method of finite differences may be used to obtain a numerical solution to the partial differential equations for turbulent flow. The equations and their simplest corresponding central difference equations are as follows:

$$\frac{\partial P}{\partial X} = V^n + \frac{\partial V}{\partial T} \qquad 1.$$

$$\frac{1}{2\overline{X}}[P_r - P_l] = V_o^n + \frac{1}{2\overline{T}}[V_a - V_b] \qquad 11.$$

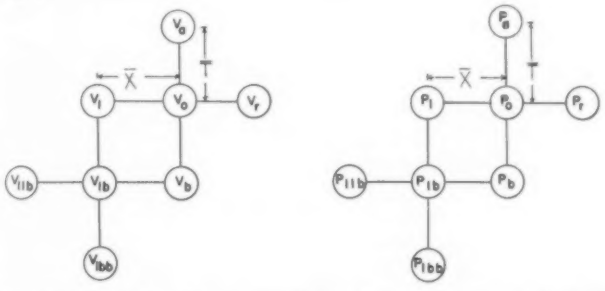
$$\frac{\partial P}{\partial T} = \frac{\partial V}{\partial X} \qquad 2.$$

$$\frac{1}{2\overline{T}}[P_a - P_b] = \frac{1}{2\overline{X}}[V_r - V_l] \qquad 12.$$

$$\frac{\partial^2 X}{\partial V^2} = nV^{n-1}\frac{\partial V}{\partial T} + \frac{\partial^2 V}{\partial T^2} \qquad 3.$$

$$\frac{1}{\overline{X}^2}\left[V_r - 2V_o + V_l\right] = \frac{nV_o^{n-1}}{2\overline{T}}[V_a - V_b] + \frac{1}{\overline{T}^2}[V_a - 2V_o + V_b] \qquad 13.$$

The subscripts are defined by the following diagrams or "molecules":



The third of the above equations, in which P is eliminated, makes it possible to generate a complete solution for velocity independently, by first assuming that velocity is stopped at $X = 0$ in time $T = T_{so}$. The boundary conditions are:

at $X = 0$ let $V = 1 - T/T_{so}$

at $X = T, V = 1$

Thus, the table values can be set up as follows:

T=2.2	0.0	.....	.....	.....	.....	.....	.....	.....	.....	..
T=T_{so}= 2.0	0.0	.....	.....	.....	.....	.....	.....	.....	.....	..
T=1.8	0.1	.....	.....	.....	.....	.....	.....	.....	0.977	..
T=1.6	0.2	.....	.....	.....	.....	.....	.....	0.972	1.0	1.0
T=1.4	0.3	.....	.....	.....	.....	.....	0.967	1.0	.....	..
T=1.2	0.4	.....	.....	.....	.....	0.960	1.0	.....	.....	..
T=1.0	0.5	.....	.....	.....	0.952	1.0	.....	.....	.....	..
T=0.8	0.6	.....	0.858	0.942	1.0	.....	.....	.....	.....	..
T=0.6	0.7	0.831	0.931	1.0	.....	.....	.....	.....	.....	..
T=0.4	0.8	0.917	1.0	.....	.....	.....	.....	.....	.....	..
T=0.2	0.9	1.0	.....	.....	.....	.....	.....	.....	.....	..
T= 0	1.0	.....	.....	.....	.....	.....	.....	.....	.....	..
X=	0	0.2	0.4	0.6	0.8	1.0	1.2	1.4	1.6	..

For the first numerical value, let the circled square be V_o and solve the difference equation 13 for the value V_a, immediately above the circled square:

$$V_a = \frac{V_r + V_l + V_b\left(1 - \frac{n\overline{T}}{2}V_o^{n-1}\right)}{1 + \frac{n\overline{T}}{2}V_o^{n-1}} \qquad 14.$$

for a square lattice in which $\overline{T} = \overline{X}$.

To show an example, the case where flow is stopped in time $T_{so} = 2$ will be used. Since the above table is set up with ten spaces from $T = 0$ to $T = T_{so}$, then the spacing between "pivotal points" is $\overline{T} = \frac{T_{so}}{10} = 0.2$. Also, for simplicity let the exponent n be equal to 2, so the difference equation reduces to

$$V_a = \frac{V_r + V_l + V_b(1 - 0.2V_o)}{1 + 0.2V_o}$$

The first value is at $T = 0.4$, $X = 0.2$

$$V_a = \frac{1.0 + 0.9 - 1.0(1 - 0.2 \times 1.0)}{1 + 0.2 \times 1.0} = 0.917$$

Having obtained this value, the next can be found by shifting diagonally upward and to the right by one position and solving for V_a at $T = 0.6$ and $X = 0.4$. The equation is

$$V_a = \frac{1.0 + 0.917 - 1.0(1 - 0.2 \times 1.0)}{1 + 0.2 \times 1.0} = 0.931$$

Continuing with this procedure, one obtains all of the values needed along the diagonal line upward and toward the right, as shown.

For the next sequence, the pivotal point V_o is set at $X = 0.2$ and $T = 0.4$, where $V = 0.917$. The procedure outlined above is followed to obtain all necessary values of V on the next diagonal line upward and to the right.

These sequences can be repeated indefinitely to obtain all values of V desired. Although it is always necessary to assume the values of V in the column, $X = 0$, one is free to make any desired assumptions. For example, the flow need not be stopped at a uniform rate as shown in the example; also, after stopping the flow at time $T = T_{so}$, it may then either remain stopped or it may be re-started in any desired fashion as time increases.

The next part of the solution is to find the values of pressure from Equations 11 and 12. In the case of P, the initial values are known only along the diagonal $X = T$. Looking at the "molecule" for pressure, it may be observed that P_l can be obtained in two ways; first, by applying equation 11 at the pivotal point, P_o and solving for P_l, and second, by applying Equation 12 at the Point P_{lb} and solving for P_l. These give respectively (for $\overline{X} = \overline{T}$):

$$P_l = P_r - 2\overline{T}V_o^n + V_b - V_a$$
$$P_l = P_{lbb} + V_b - V_{llb}$$

These two equations for P_l must be satisfied individually as well as simultaneously, but these conditions could only be satisfied when $\overline{X}$ and $\overline{T}$ are taken to be infinitesimal. However, for practical values of $\overline{X}$ and $\overline{T}$ the average value of P_l will be used. Then, adding the two equations and dividing the result by two, the following equation is obtained.

$$P_l = \tfrac{1}{2}(P_r + P_{lbb} + 2V_b - V_a - V_{llb} - 2\overline{T}V_o^n) \qquad 15.$$

In this equation, P_r is two spaces to the right and P_{llb} is two spaces below the unknown P_l, so only alternate values of P in the lattice need be calculated. The procedure is similar to the foregoing solution for V, starting from known values on the diagonal line, $X = T$ and calculating from $X = 0$ toward the right and upward along each diagonal. The solution can be carried as far as values of V are available to solve Equation 15. The resulting pressure distribution is, of course, completely dependent upon the corresponding velocity solution and no independent assumptions can be made regarding pressure if this numerical procedure is followed.

For the example started above, in which flow is stopped at a uniform rate in time $T_{so} = 2.0$ using a square lattice with spacing $\overline{X} = \overline{T} = 0.2$, Tables I and II show the completed solution up to the time when flow is stopped. It is noted that certain values of V to the left of $X = 0$ are obtained from Equation 14 for use in Equation 15 as V_{llb} where P_l is in the column

About the Author

Richard R. Burnett joined Trans-Arabian Pipe Line Co. in 1949 as a mechanical engineer. In May of 1958 he was promoted to assistant chief engineer—for pipe line. He graduated from the University of California in 1949 with a B.S. degree in electrical engineering. In 1954 he received his M.S. degree from Columbia University.

$X = 0$. A negative value of V to the left of $X = 0$ merely means that flow must be reversed in the downstream region in order to stop the flow at $X = 0$, the location in question. (The point $X = 0$ may be reasonably regarded as any point along a pipe line which extends continuously in both directions.)

This agrees with the result obtained by Krahula, who used a different numerical procedure. The numerical computation given in Tables I and II is shown graphically in Figure 7.

TABLE 1—Values of V

Numerical Solution for V, with turbulent flow stopped uniformly at $X = 0$ in time $T = 2.0$. Turbulent Flow, $n = 2$. Explanation given in Appendix III.

T \ X	—0.2	0.0	0.2	0.4	0.6	0.8	1.0	1.2	1.4	1.6	1.8	2.0	2.2
2.2	.....	0.0	.08009	.25543	.41859	.56282	.68564	.78441	.86185	.91802	.95853	.98386	1.0
2.0	.....	0.0	.17908	.34986	.50465	.63926	.74985	.83792	.90298	.95040	.98063	1.0	1.0
1.8	—.08082	0.1	.27682	.44131	.58759	.71057	.81023	.88533	.94071	.97675	1.0	1.0	1.0
1.6	.....	0.2	.37297	.53049	.66621	.77833	.86466	.92918	.97210	1.0	1.0	1.0	1.0
1.4	.12008	0.3	.46792	.61646	.74177	.84054	.91549	.96652	1.0	1.0	1.0	1.0	1.0
1.2	.....	0.4	.56110	.70012	.81249	.89927	.95982	1.0	1.0	1.0	1.0	1.0	1.0
1.0	.32703	0.5	.65297	.78003	.88010	.95178	1.0	1.0	1.0	1.0	1.0	1.0	1.0
0.8	.....	0.6	.74264	.85751	.94213	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
0.6	.54101	0.7	.83099	.93056	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
0.4	.....	0.8	.91667	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
0.2	.76400	0.9	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
0.0	.....	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0

TABLE 2—Values of P

Numerical Solution for P with turbulent flow stopped at $X = 0$ in time $T = 2.0$ with values of V given in Table I. Turbulent flow, $n = 2$. Explanation given in Appendix III.

T \ X	0.0	0.2	0.4	0.6	0.8	1.0	1.2	1.4	1.6	1.8	2.0
2.0	1.56055	...	1.37873	...	1.31253	...	1.41233	...	1.65855	...	2.0
1.8	.....	...	.....	...	.....	...	.....	...	.....	1.8	2.0
1.6	1.20082	...	1.06702	...	1.09040	...	1.28291	...	1.6	1.8	2.0
1.4	.....	...	.....	...	.....	...	.....	1.4	1.6	1.8	2.0
1.2	.85131	...	.79315	...	.91796	...	1.2	1.4	1.6	1.8	2.0
1.0	.....	...	.....	...	.....	1.0	1.2	1.4	1.6	1.8	2.0
0.8	.52440	...	.56694	...	0.8	1.0	1.2	1.4	1.6	1.8	2.0
0.6	.....	...	.....	0.6	0.8	1.0	1.2	1.4	1.6	1.8	2.0
0.4	.23445	...	0.4	0.6	0.8	1.0	1.2	1.4	1.6	1.8	2.0
0.2	.....	0.2	0.4	0.6	0.8	1.0	1.2	1.4	1.6	1.8	2.0
0.0	0.0	0.2	0.4	0.6	0.8	1.0	1.2	1.4	1.6	1.8	2.0

The accuracy of the numerical solution may be improved through use of closer spacing of values. An alternate method to obtain better accuracy is the use of two or more numerical solutions to the same problem, but with different intervals between values, and then to apply the so-called Richardson's Extrapolations (6). This procedure is derived fundamentally from the fact that the error in the numerical solution is greater for larger spacing and that the order of the error in a given spacing can be determined by taking into account the terms of the infinite series, describing a derivative, which are dropped by using only the simple expressions given above. If two different spacings are used, the extrapolation formula is

$$A_{n_1 n_2} = \frac{n_2^2}{n_2^2 - n_1^2} A_{n_2} - \frac{n_1^2}{n_2^2 - n_1^2} A_{n_1} = d_1 A_{n_1} + d_2 A_{n_2} \quad 16.$$

where A_n is the result if n_1 values were computed within the given interval, and A_{n_2} results from using n_2 values in the same interval. If n_2 is twice as many as n_1, then the extrapolation formula reduces to:

$$A_{n_1 n_2} = 1.3333 A_{n_2} - 0.3333 A_{n_1}$$

To apply this extrapolation method to the foregoing example, a numerical solution using $\overline{X} = \overline{T} = 0.4$ was calculated, thus giving only five values in time from 0 to $T_{so} = 2.0$. The final pressure at $X = 0$ and $T_{so} = 2.0$ was 1.54645, while that obtained for the closer spacing shown in Table II was 1.56055. Then the extrapolated value is

$$P_{so} = 1.3333 \times 1.56055 - 0.3333 \times 1.54645 = 1.565$$

Numerical solutions have been calculated similarly for flow stoppage in time $T_{so} = 1.0$ and $T_{so} = 3.0$ and the results are given in the graph, Figure 8.

A somewhat similar numerical pattern can be followed for solving cases in which turbulent flow is increased from an initial steady flow rate or in which flow is started from a static condition.

APPENDIX IV

The following numerical example is given to illustrate the use of the wave front attenuation curve. Assume that pressure is to be raised by a given amount within a specified time at the downstream end of the line under turbulent flow. Pressure and time are then converted to dimensionless form, using the definitions in Appendix I, thus obtaining $P_{so} = 1.10$ and $T_{so} = 2.00$. From Figure 8, the value of V_{so} is found to be 0.33. The remote location on the pipe line is at a distance which is converted to dimensionless form as $X = 1.00$. The abscissa of Fig-10 is computed as follows:

$$\frac{X(1 - V_{so})}{P_{so} + 1 - V_{so}} + \tanh^{-1} V_{so}$$

$$= \frac{1.00(1 - 0.33)}{1.10 + 1 - 0.33} + \tanh^{-1}(0.33)$$

$$= 0.379 + 0.293$$

$$= 0.672$$

From Figure 10, the ordinate is 0.43, or

$$P_s \frac{1 - V_{so}}{P_{so}} = 0.43$$

Solving for P_s:

$$P_s = 0.43 \left(\frac{P_{so}}{1 - V_{so}} \right)$$

$$P_s = 0.43 \left(\frac{1.10}{1 - 0.33} \right)$$

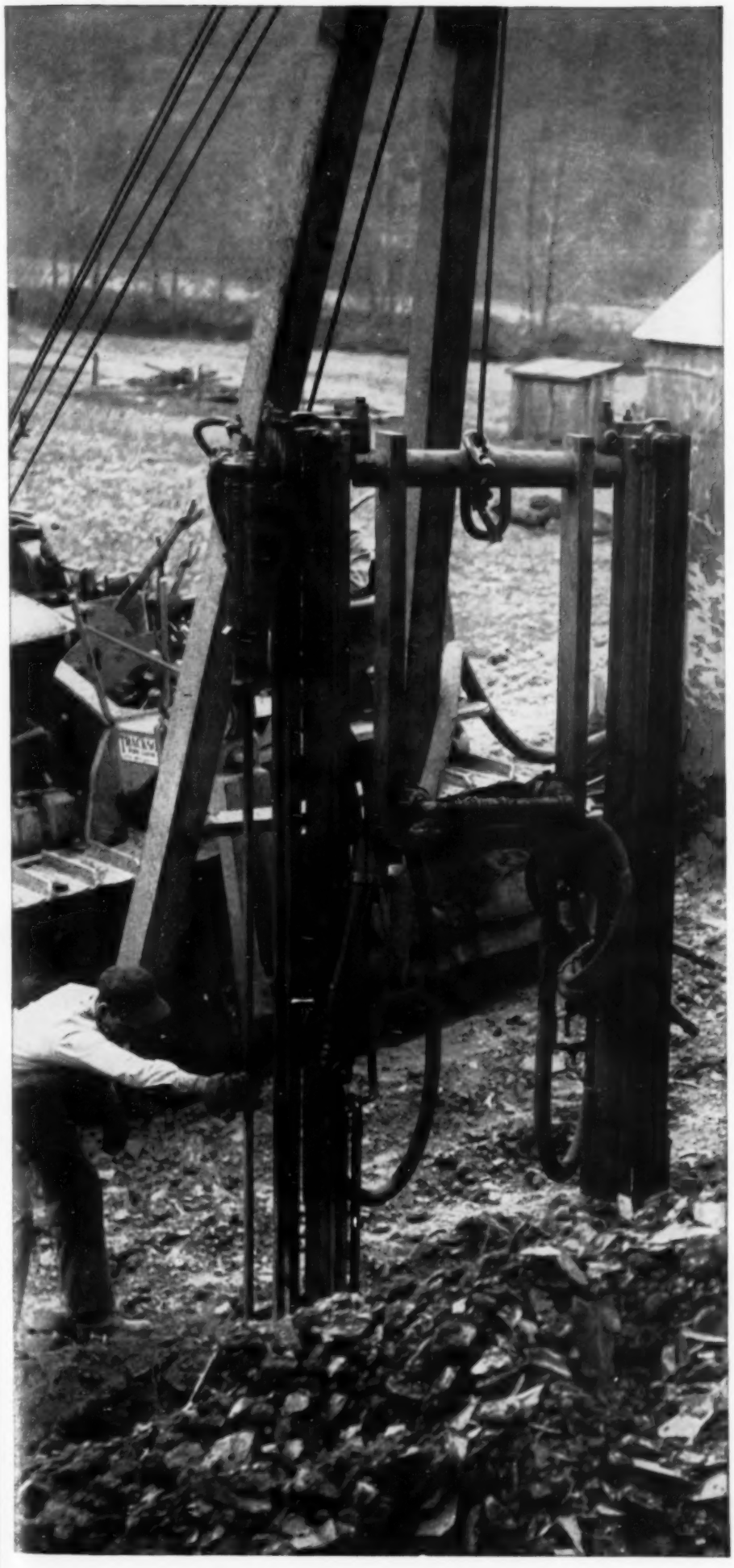
$$P_s = 0.71$$

This result is then converted back to pressure by using the definition

$$P_s = pg/a\rho v'$$

$$\text{or} \quad p = P_s \left(\frac{a\rho v'}{g} \right)$$

—The End



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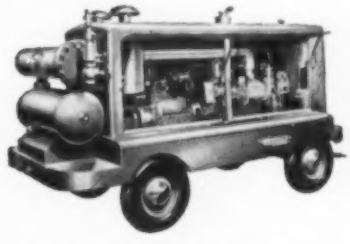

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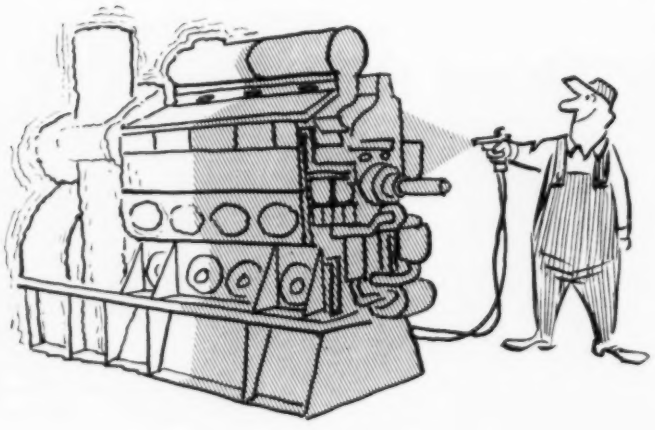
By Donald M. Taylor, Engineering Editor

Spray-On Coatings Act as Vibration Dampener



Viscoelastic materials that can be painted on vibrating machine members to dampen the vibrations they emit are now available from at least four different manufacturers. These coatings dampen the vibrations by converting them into shearing forces that are dissipated within the viscoelastic.

Ordinarily, springs serve best to isolate low frequency vibration, and pads of rubber, cork, felt, etc., are used for high speed vibration. But the latter materials usually lose a great deal of their effectiveness with age; in many instances, the viscoelastic coatings are cheaper to begin with.

One of the advantages of the vibration dampening coatings is that resonance is no problem.

Would this make a good internal coating for discharge piping?

What Every Man Needs—A Diamond Making Machine

Now here's a bargain if I ever heard of one! For a mere $10,000 you can buy an ultra high-pressure machine that can convert graphite into diamonds. For $60,000 you can get a machine with a 5.5 cubic inch cavity—and this must mean bigger diamonds yet!

The machines in question are manufactured by F. H. McGraw and Co., and they develop pressures up to 1.5 million psi and a temperature of 5,000° F. Motive power for such elevated pressures come from 30,000 psi water, which forces a number of anvils to converge on a small cavity. Until now, such cavities were limited to about $\frac{1}{64}$ cubic inch. But, models of the new machine have cavities up to 15-inch cubes.

The uses will be many: 1. Phase transformation—i.e., changing graphite into diamonds; 2. Densification—metallic powders can be compressed to almost 100 percent density; 3. Alloying—certain chemicals that cannot be combined by other methods will probably yield to the great pressure and temperature.

As for me, I would just as soon make diamonds. And just think what a bachelor could do with such a device!

Ultrasonic Waves Utilized in New Type Meter

A new meter which uses ultrasonic waves to measure flow. The principle: A transducer produces the ultrasonic sound waves on one side of the meter, and two receiver crystals on the other side of the meter, spaced above and below the sound source pick up equal volumes of sound when there is no flow. But when there is flow, the sound waves are deflected, and one crystal picks up a greater volume than the other.

Developer of the meter is Hersey-Sparling Meter Co., Dedham, Mass., and Gulton Industries. It is now being marketed for sewage and water flow, but the developers predict there will be meters for other products soon.

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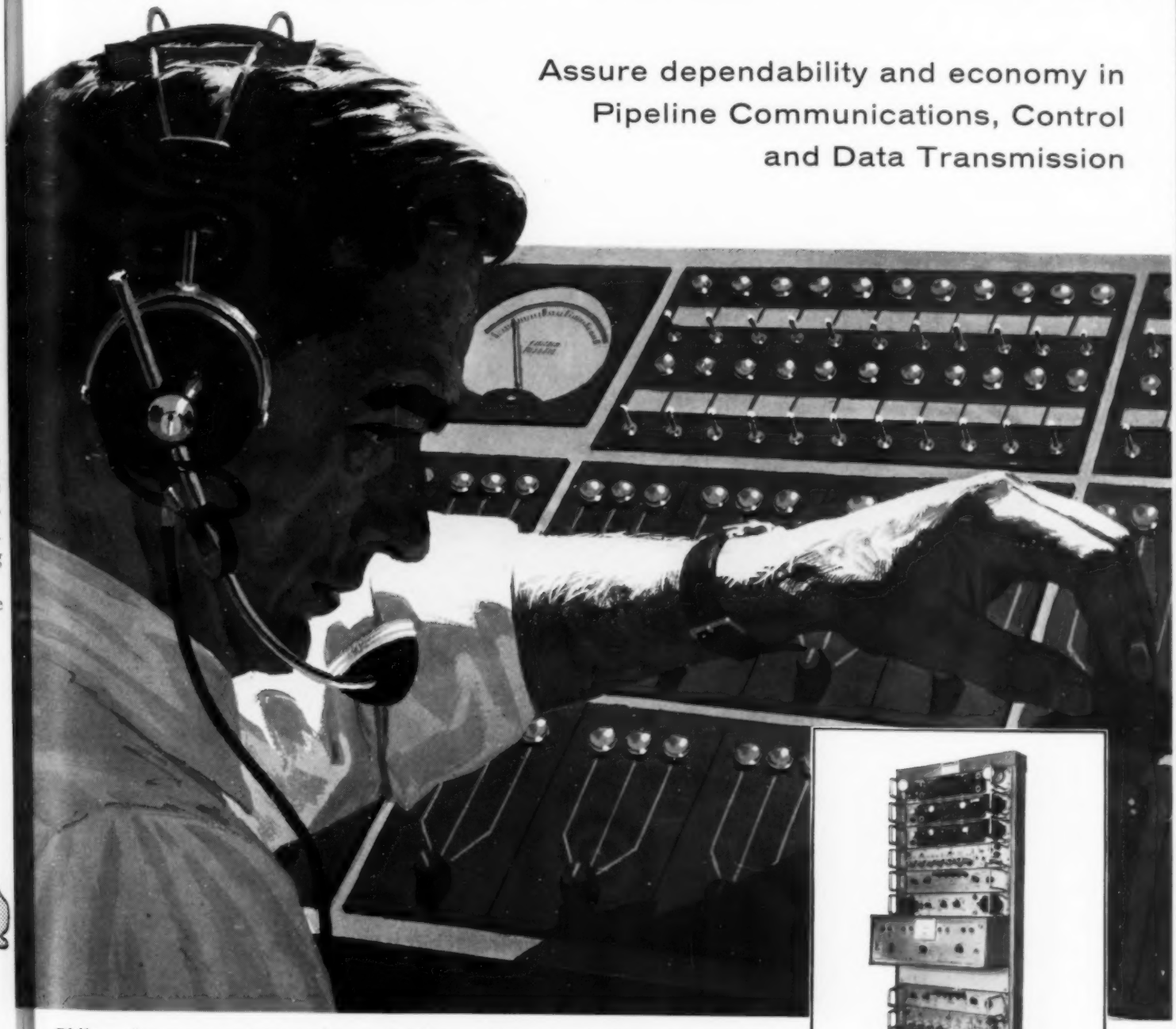

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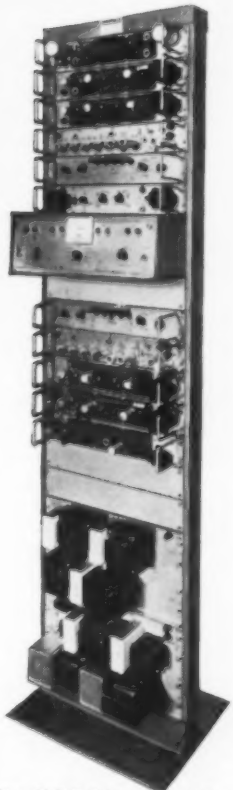

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New Developments for Industry Announced

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A new diesel fuel that cuts wear of injectors, burns better, reduces costly repairs and gives maximum power and mileage with minimum engine deposits, smoke and odor has been announced by Standard Oil Co. of Indiana. The new fuel is not for home heating and other services —it is designed solely for consumption in diesel engines.

Spiral Weld Pipe at Jobsite

A pipe mill that manufactures spiral weld pipe on the job was developed by a Czech refugee, Dr. Vilem Eckhard, and is being manufactured in West Germany. The mill uses coils of steel plate, fashions them into almost any desirable size pipe, and makes the longitudinal weld right out on the job.

Clear-water Cone on TV Camera

A clear water cone formed by a pyramidal envelope of plastic laminate with a curved front and filled with clear water is improving special TV cameras used for inspecting underwater installations. Inside the cone are two 1,000 W reflectors placed so there is no reflection on the face of the lens. This equipment was developed by French scientists.

Flameless Gas Burner

The Gas Appliance Manufacturers Association has announced that a new flameless gas burner "which is not really a burner at all" eliminates most of the heat waste of ordinary heaters, stoves and burners. The combustion of a gas-air mixture takes place in a thin tube made of flexible material that can be readily turned and shaped to fit into small space and produce heat directly where it is needed and not in the surrounding atmosphere.

Free-Piston Engine for the Home

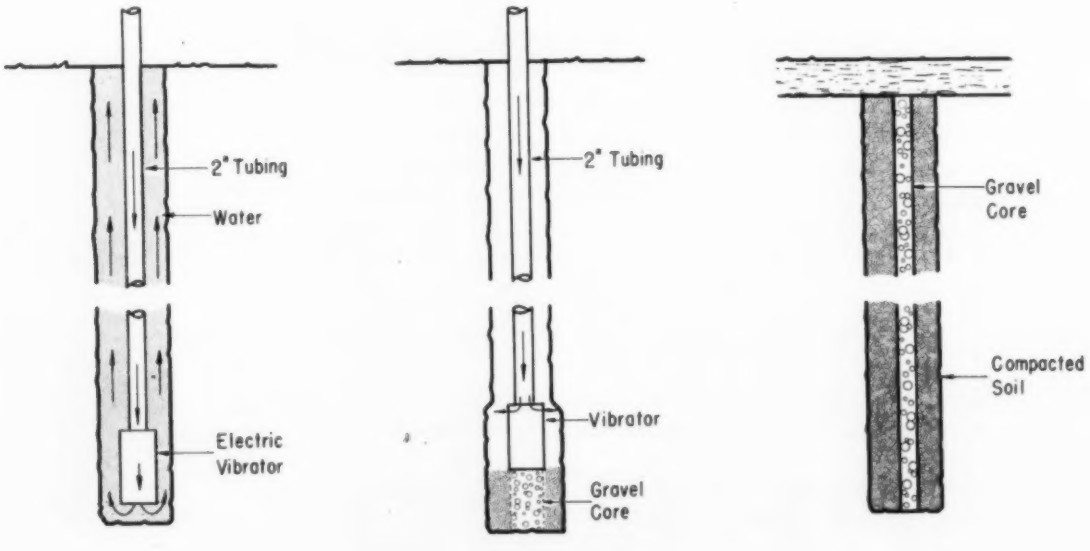
The president of the Gas Appliance Manufacturers Association predicted that we will soon be using a gas-powered free-piston engine to furnish power for the home air conditioner. He also predicted that gas will figure in a home "power center" that air conditions the entire house, purifies the air and furnishes all the energy needed in the kitchen.

New Way to Stabilize Soil for Foundations

This idea comes from Germany, and according to reports it was used successfully in stabilizing some 100,000 square feet of building area on a power station site. Here's the way it works:

Using a light drilling rig, operators wash an electric vibrator to the proposed depth of stabilization by jetting a high-pressure stream of water out the nose of the vibrator. When the device reaches bottom, the water course is changed to wash the sides of the hole down on top of the vibrator. The vibrator compacts this soil as it is slowly withdrawn from the hole.

The technique can be varied to inject a column of gravel in the hole directly under the vibrator as it stabilizes the surrounding soil. The net effect of this method is to construct hard subsurface soil pillars. In the case of the power station site, about 2,000 of these pillars were vibrated in about six weeks. Their depths were about 90 feet. In some cases the upper portion of the pillars were concreted.



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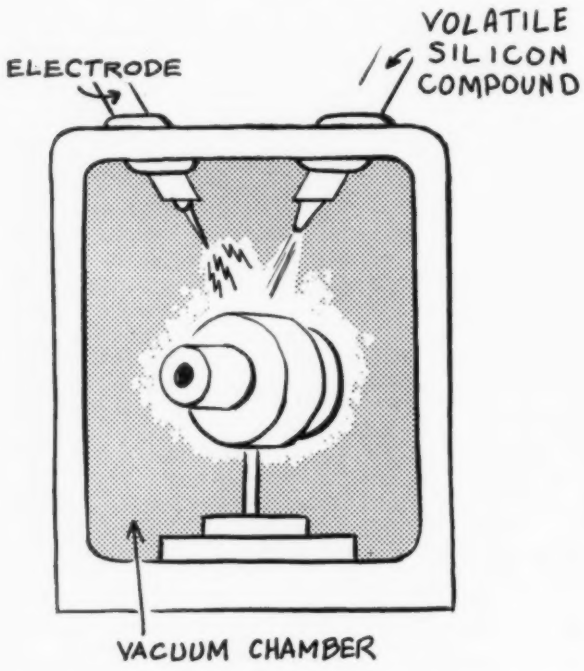
A new technique for cladding ordinary carbon steel with a non-corrosive high silicon alloy has been developed



by Allis-Chalmers. The coating is applied in a vacuum chamber containing an electrode and the steel to be coated. A volatile compound of silicon is passed through the chamber; the gaseous form of silicon is activated by the electrical discharge from the electrode, and the cladding is uniformly applied, regardless of the shape of the metal part. Thickness of the alloy is determined by the duration of the treatment. The silicon coating is proving highly effective against chemical attack of corrosive acids.

Resonance Bending to Test Pipe

Successful application of resonance bending is reducing to minutes the time required to determine the probable years of service in the life of metal pipe, according to Tube Turns Division of Chemetron Corp. The pipe is pressured up and set to vibrating in its natural resonance frequency, and literally shakes itself to the point of fatigue failure. The vibrations come from eccentric weights spun by an electric motor, which on a typical test produces something like 4,000 cycles per second.

The main "trick" in this type testing is to make sure of the resonance. The pipe is suspended at points which match the natural node points which together with the pipe's natural frequency as based on metal thickness, length, etc., can wreak havoc in short order. Once the natural frequency of the pipe has been established, the amplitude of vibration can be increased by stepping up the output of the motor.

High Speed Ultrasonic Weld Tester

A new ultrasonic flaw detector that has the speed necessary to keep up with high capacity pipe production has been developed by scientists in the Netherlands. The device gives good differentiation in both directions and depth in locating transverse cracks, gas occlusions, etc.

Rules of Thumb

and Engineering Data Sheets for the Pipeliner's field notebook

$25 for Engineering Data Sheet $15 for Rule of Thumb

These practical aids give quick, reasonably accurate answers to design, maintenance and cost estimating problems. PIPE LINE INDUSTRY will pay $25 for each chart, nomograph or data sheet published—$15 for each Rule of Thumb. Send your ideas to PIPE LINE INDUSTRY, P. O. Box 2608, Houston, Texas

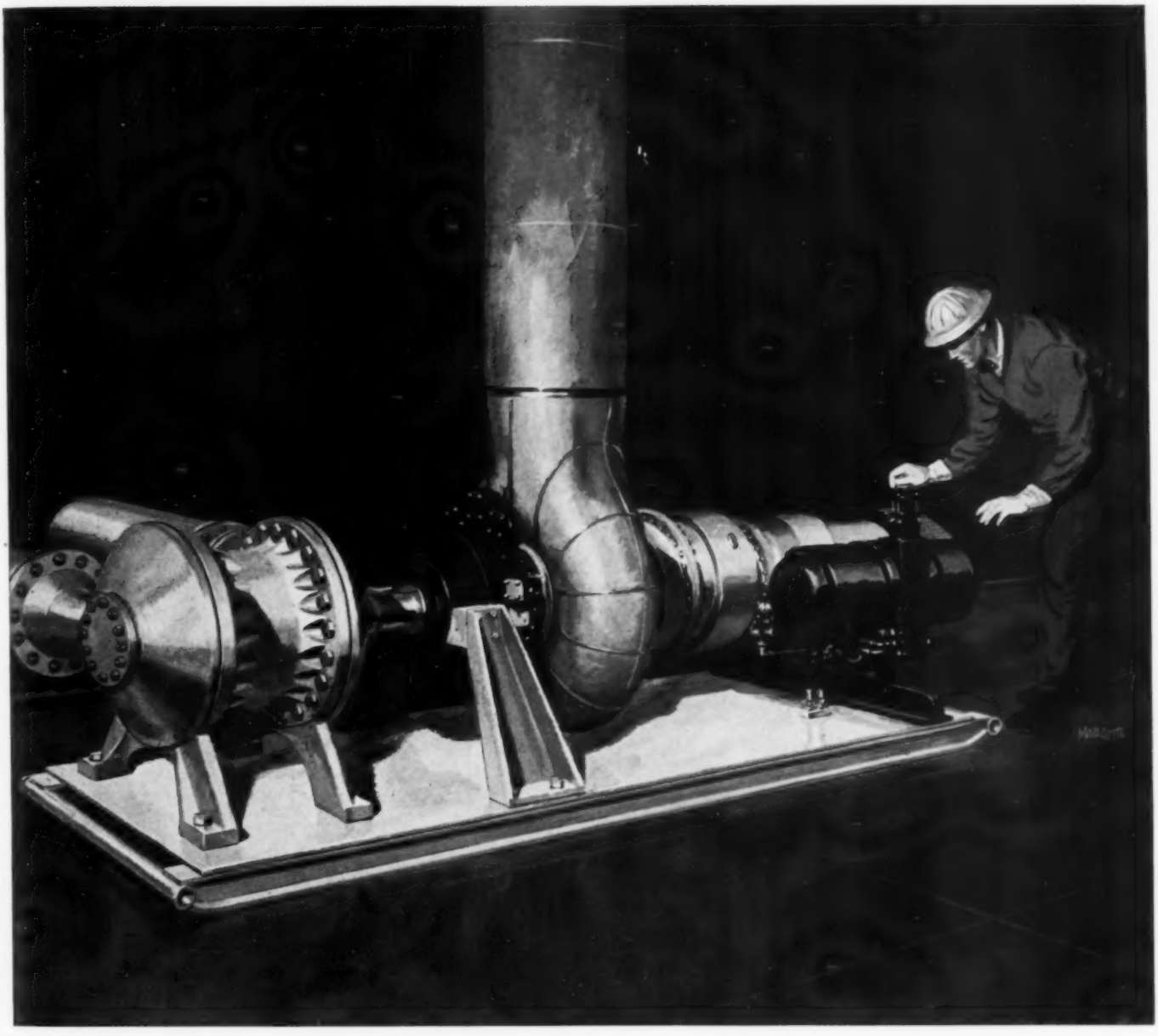
Engineering Design —75— **How to Estimate the Head for an Average Centrifugal Pump**

By slightly modifying the basic pump formula, $H = \left(\frac{D\,N}{1840\,K_u}\right)^2$ it is possible to **find a means of estimating the head a pump will develop for each impeller at various speeds.** The terms are defined as follows:

H = Head in feet
D = Diameter of the impeller in inches
N = Rpm of the impeller
K_u = Pump design coefficient. The values of this expression may vary from 0.95 to 1.15. For estimating purposes substitute 1,900 for 1,840 K_u. The formula becomes, $H = \left(\frac{D\,N}{1900}\right)^2 \times$ (the number of impellers)

Example: What head will be developed by a well designed centrifugal pump with four 11.75-inch impellers turning at 1200 rpm?

$$H = 4 \times \left(\frac{11.75 \times 1200}{1900}\right)^2 = 4 \times 7.4^2 = \text{feet of head.}$$



UNIQUE NEW COMPRESSOR

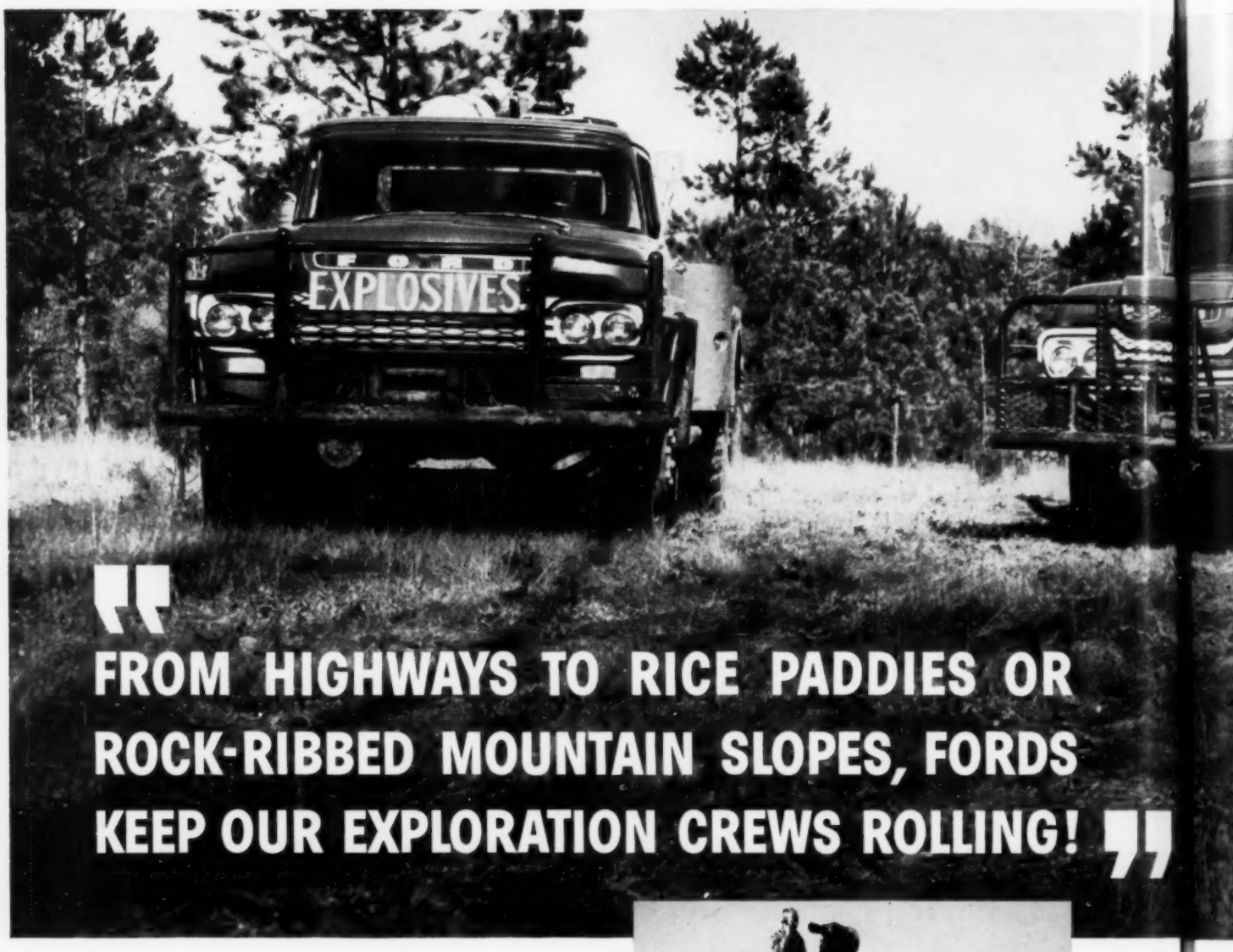
Solar industrial gas turbine-driven centrifugal compressor offers advantages found in no other type

SOLAR'S LIGHTWEIGHT centrifugal compressors incorporate unique new features for applications in the low-volume range. They operate in a range of flows and pressures new to centrifugal equipment. Interchangeable compressor wheels and other parts permit quick, low-cost field changes to accommodate new flow and pressure requirements. Ideal for main pipeline stations as well as field use, they can be started or shut down in seconds—even by remote control—and are ideal for unattended operation.

Designed to match the high rotating speeds of Solar gas turbine drivers, Solar's new compressor packages are small and lightweight (a fraction of the weight of conventional piston-driven units). They require only the lightest foundations. Maintenance is simple. Easy portability allows periodic inspection at a central shop.

A new illustrated brochure describes in detail Solar centrifugal gas compressors. Write for it to Dept. H-113, Solar Aircraft Company, San Diego 12, California.

SOLAR
AIRCRAFT COMPANY



"FROM HIGHWAYS TO RICE PADDIES OR ROCK-RIBBED MOUNTAIN SLOPES, FORDS KEEP OUR EXPLORATION CREWS ROLLING!"

says Jack McManus
Equipment Manager
Geophysical Service Inc.
Dallas, Texas

"Our world-wide oil exploration operations are often similar to those of an army task force . . . only we have to show a profit. In remote areas logistics is of prime importance. If replacement parts and supplies are not immediately available, the need for a bolt or a bearing may hold up an operation and cost thousands of dollars in lost time. Under these conditions, inherent vehicle ruggedness, ease of maintenance and parts availability are 'musts' for keeping our seismic crews in operation.

"We have 138 Ford Trucks from ½-ton pickups to F-800 Heavy Duties. These Fords, many of which are 1960 models, are used for party chief vehicles, recording, water, shooting, drill, survey, transportation, utility and gravity meter trucks.

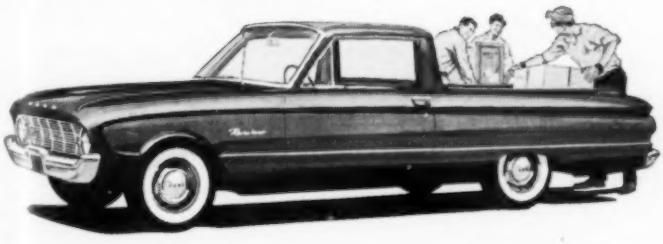
"Many of our field people have been behind the wheel of Ford Trucks for 15 or 20 years . . . *and they sure like Fords.*"

Surveying with radar, this GSI surveyor uses a "Tellurometer" mounted on a special platform over the Ford F-250's cab. This new electronic, line-of-sight device is used for long survey traverses for seismic operations in West Texas and similar areas of the world. Elevated above the brush, a 10- to 15-mile line can be accurately surveyed from a single setup.

Now at your Ford Dealer's

FORD Falcon RANCHERO

America's lowest-priced* pickup truck!



The Falcon Ranchero is priced lower than any pickup in America with comparable standard equipment! And that is just the beginning of your savings. Single-unit construction saves on maintenance . . . it's tighter, quieter, with main underbody structural members zinc-coated against rust and corrosion. Front fenders bolt on, cost less to replace. And Ranchero's passenger-car ride and handling ease lessen driver fatigue.

UP TO 30 MPG!

Totally new for *total* savings! Ford's new Falcon Ranchero delivers up to 30 miles on a gallon, yet its new 90-hp Six is geared to do a real job! There's lower costs for oil, tires, brakes, replacement parts . . . nearly everything!

BIG 6-FOOT BOX!

Capacity is more than ample for most pickup hauls—nearly 8 feet of load length with tailgate flat. And thanks to the low floor height, loading and unloading is faster, easier!

FEATURES:

1. Up to 30 miles on a single gallon
2. 4,000 miles between oil changes
3. Diamond Lustre Finish needs no waxing
4. Low loading height
5. Instant-lock tailgate opens, closes with a single, one-hand motion
6. Roomy comfort for three adults
7. Styled to capture admiration

*Based on a comparison of latest available manufacturers' suggested retail delivered prices with comparable standard equipment

See the parade of pickups during your FORD DEALER'S TRADING FAIR

How to do it

PIPE LINE HINTS

$10 is paid for each illustrated acceptable contribution. Mail to The Editor, PIPE LINE INDUSTRY, P. O. Box 2608, Houston 1, Texas

Four-Ton Side Boom Truck Constructed From Rebuilt Autocar

What is the most important characteristic of a good pipeliner? Perhaps it is his ingenuity.

If this is true, the pipeliner who thought up this side-boom truck is certainly a good pipeliner, for this is an ingenious development. The truck has a side-boom which has a hydraulically controlled counterweight. On a number of occasions it has lifted 8,500-pound loads and traveled with them.

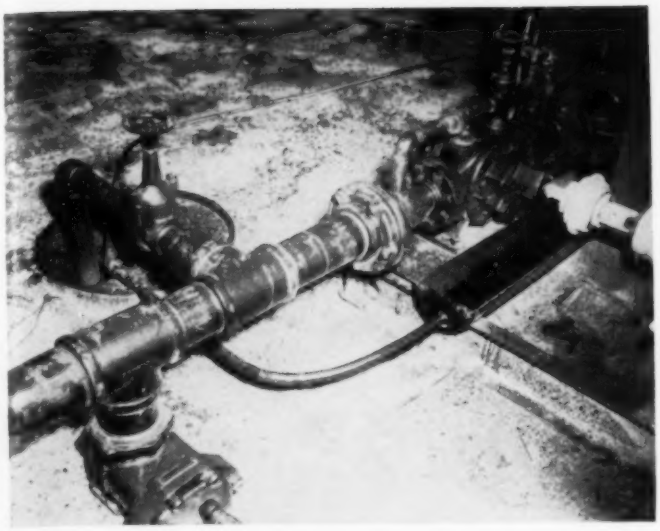
Here's the way the side-boom was installed. The truck, a World War II 4 by 4 auto car, was completely rebuilt. Then the boom, constructed of 4-inch pipe, was added and an ordinary truck winch was turned sideways on the bed to operate the load line.

A hydraulic pump was fitted to the camshaft by means of V-bolts. It powers the rams on the counterweight and the boom hoist. A valve manifold located in the cab to the driver's right enables him to raise and lower the counterweight as well as the boom.

Fan-Shaped Guards Restrict Trespassing on Pipe Line

An exposed pipe line, such as one crossing a drainage ditch, offers a challenge to the venturesome boy; unless protected it can result in injury and possible lawsuit against the operating company.

One company protects its crossing with fan-shaped guards, bolted to the pipe itself, and made with sloping lower frame members to reduce toe-hold. To be effective against trespassers, such a guard must be located past the point where it is possible to climb onto the pipe beyond the guard, or from a pipeline bent. Height of the guard also must be sufficient to prevent straddling it for footing on the high side of the line.

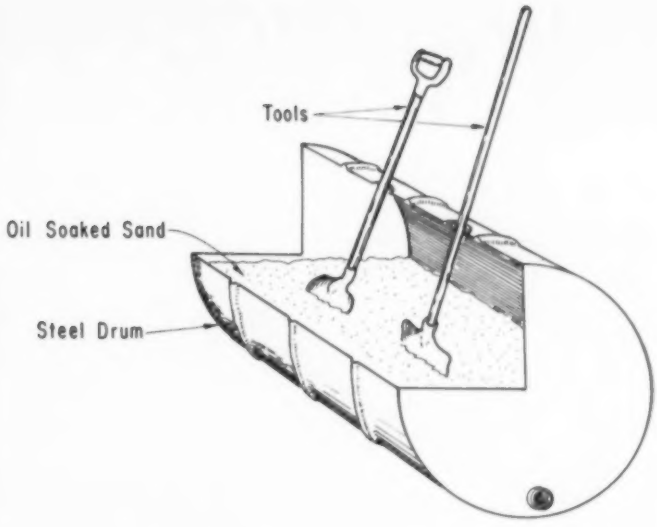


What to Do About Leakage At Field Pump Stations

Packing gland leakage at field booster stations has always constituted something of a fire hazard, a threat to good housekeeping and a waste of crude oil.

Here is one solution to this problem. Construct a trough of light-weight pipe, close up the ends as shown. Then, run a one-inch line to a buried 55 gallon drum. Pipe a side connection from the pump suction into the drum so it can be emptied into the pipe line when it gets full.

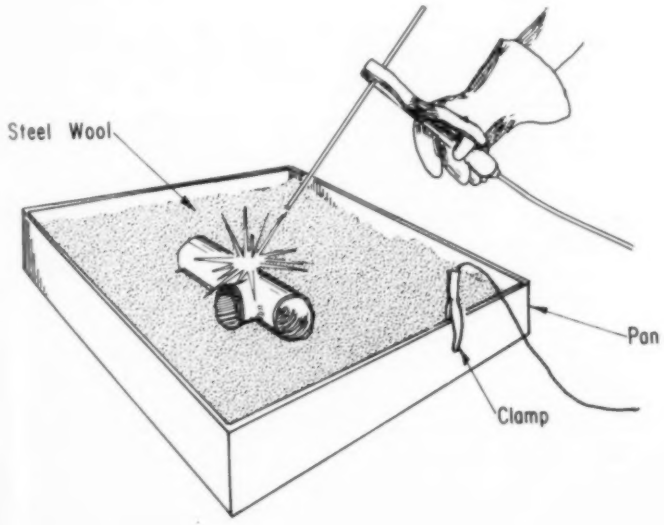
The cost is negligible, the advantages are many.



Rack Made from Oil Drum Prevents Tools from Rusting

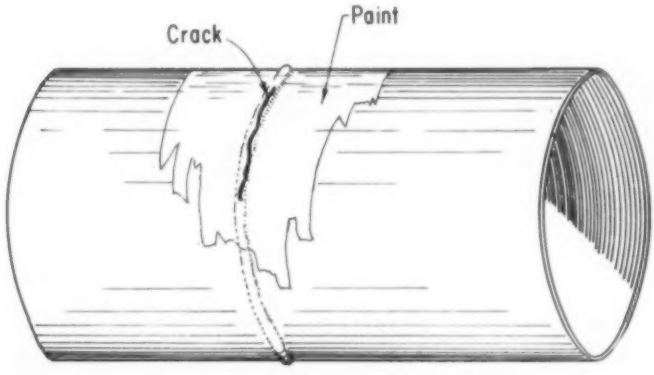
An outdoor tool rack which prevents tools from rusting can be made from used oil drums. To make them, first cut a quarter of the drum away as shown and notch the upper part to hold the handles of the tools. For drainage, the bung should face downward.

Fill the drum with sand, and add oil to prevent rust. After tools have been used, they can be worked in the sand for cleaning and then stored in sand as shown.



Use Steel Wool to Support Small Casting in Welding

Sometimes two welding leads are too many. One way to simplify the welding task on small intricate castings is to lay the castings in a metal pan filled with steel wool. Attach the welding lead to the pan. Then, no matter how the casting is turned, it will have adequate ground, and, at the same time, the lead will not be in the way of the work.



Make Dye Penetrant to Find Cracks in Metal

Here's a method of detecting fatigue cracks, etc., in metals which is inexpensive, fairly accurate and sensitive. It may possibly fall right in line with routine maintenance, requiring little outlay of time or money.

Add a small amount of machine oil to gasoline and paint over the surface of the part to be examined. Allow it to dry, wipe clean and paint over the part with a very thin, white water-base paint. When this starts drying, the hidden cracks will show up as thin dark brown lines. Explanation? The residual oil left in the crack will interfere with the setting of the paint.

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SOONER-BOOMERS cut COSTS for you!

ONLY PROVEN SIDE BOOM ON RUBBER TIRES!

Mounted on rubber tires, the SOONER BOOMER moves at road speeds up to 27 MPH, never has to be hauled for a short move. And what's more, the SOONER BOOMER limits turf damage to a minimum—never causes pavement damage. With power steering and rubber tires, the SOONER BOOMER is highly maneuverable.

SOONER BOOMER units have been adapted to Ford, International, Case, Massey Ferguson, and other tractors.

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Works faster, harder and longer to help you make Bigger Profits!

Like the proverbial workhorse . . . Rubber-tired SOONER BOOMER can be "Harnessed" to do a multitude of jobs! Versatile attachments for the SOONER BOOMER keep it on the job all the time. Operators know that this important feature cuts the heavy cost of idle equipment. Let SOONER BOOMER help you stack up new records for fewer working days . . . lower job costs . . . better work . . . BIGGER PROFITS! Call, wire or write now for complete details.

LOWEST (a) initial cost! (b) operating and maintenance cost!

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Cut-Out Pipe Guard Protects Rear Lights

One trucker who was tired of replacing broken lights on the back of his trailer rigged up this guard made from scrap 6-inch pipe. Pipe sections were the proper length to protect all the lights on both sides of the trailer.

Over the turn signal light he cut out an arrow; where the stop and tail lights were spotted, a hole was cut large enough to show the light, yet small enough to provide protection from damage during loading and unloading of pipe.

Control Panel Framework Made From Junk Pipe

Fuse boxes and controls for electrically powered pumping equipment are conveniently mounted on this framework which is constructed from junk 2-inch pipe. The framework is welded together as shown, and set in concrete in the ground immediately adjacent to the pumping unit motor. The fuse box is mounted on the frame by means of bolts. Mounting the controls on such a frame work provides a neat, permanent installation.

16" dia. Ka-Mo drill swung from boom of truck crane prebores for pilings on Houston Freeway extension in Orange County, California.

Ka-Mo 16" drill sets record pace preboring for pilings on Houston Freeway

Bertran Drilling Co., contracted to prebore holes for cast-in-drilled hole concrete pilings on construction of Houston Freeway extension in Orange County, Calif. Job called for drilling a series of vertical and battered holes — 16" in dia. — with various depths to 72 ft. To handle work, Bertran brought in a Ka-Mo vertical drill, powered by a 34 h.p. self-contained hydraulic motor. Swung from boom of 25-ton truck crane, the 16" dia. drill bored as many as 16 holes — 55' deep — in 8 hours! At several places on job — same drill also bored eight 72-ft. holes in one 8 hr. shift. Record production — 2 to 1 over any other machine owner is familiar with — was obtained by using continuous sectionalized drill flights.

10 to 15% saving in concrete

Vic Zonver, owner of Bertran Drilling reported an unexpected saving in amount of concrete used to pour pilings bored by Ka-Mo drill. Normally, by preboring with conventional systems, hole needs 10 to 15% more concrete than estimated theoretical volume. Drilled holes by Ka-Mo continuous-auger system required only about 1% more concrete.

Pays to check

Whether your work involves angular, vertical, or horizontal drilling, it will pay you to check the Ka-Mo line. Drill sizes 2" to 48" diameter, and larger — sectionalized lengths — air, hydraulic, electric, gasoline, or diesel powered. Engineering service is always available for these special installations. Just write or call.

Mail to: KWIK-MIX CO., Ka-Mo Tools Dept., Port Washington, Wis.

☐ Send us free booklet on Ka-Mo drilling method.

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KWIK-MIX COMPANY — Ka-Mo Tools Dept.

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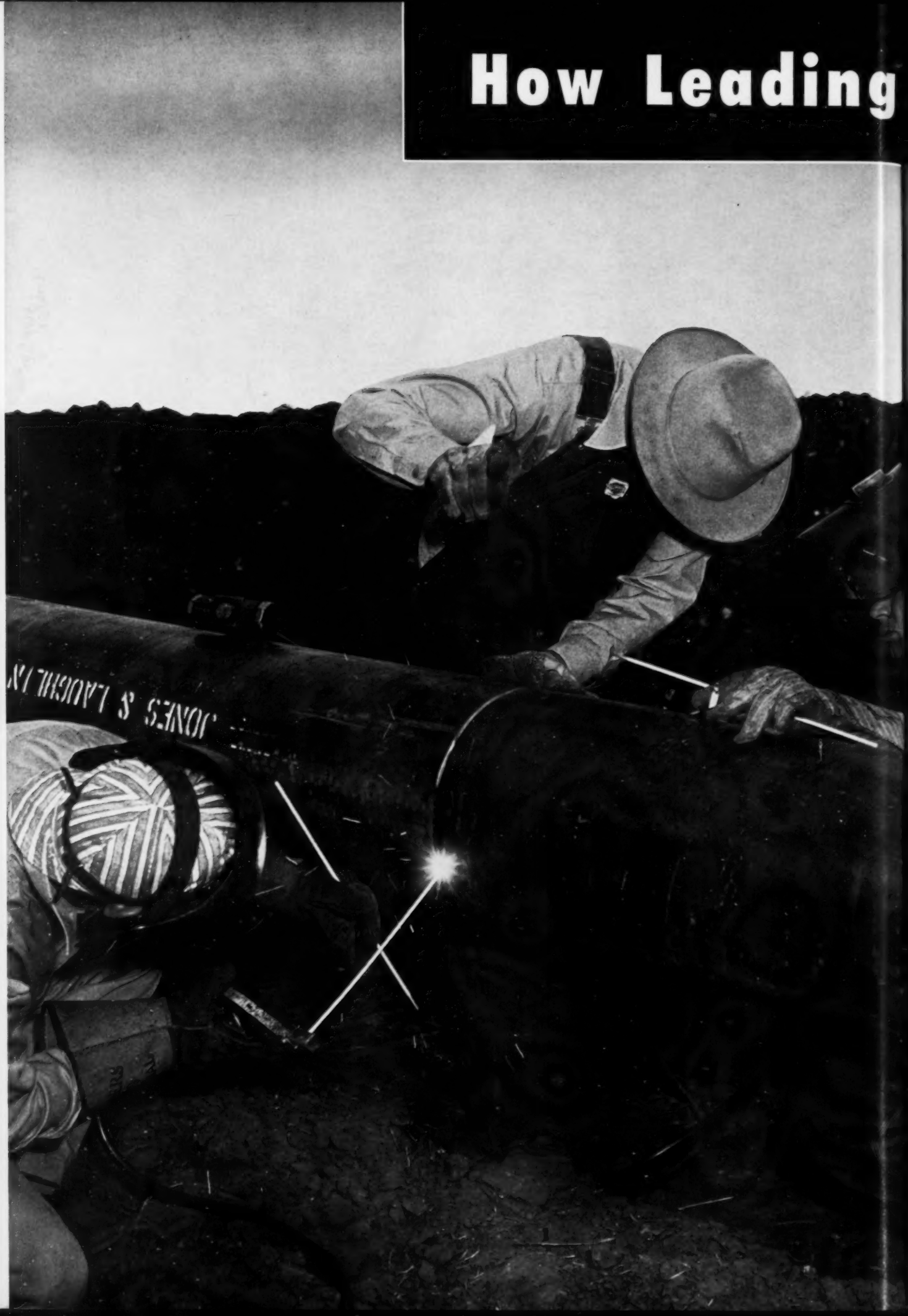
How Leading P

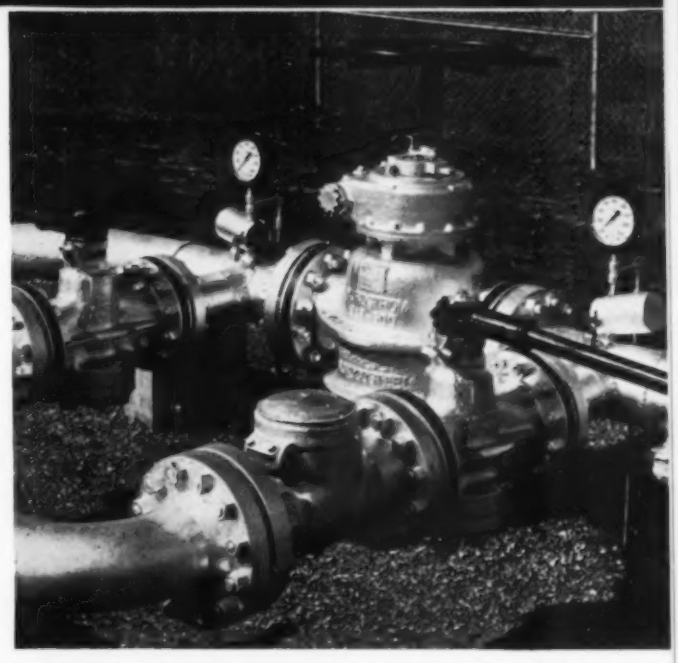


g Pipeliners Cut Costs

Leading pipeliners depend on J&L Supply for products with the latest technological advances in design and construction.

J&L pipeline products are specifically engineered for pipeline use. They make lines easier to engineer, install, and maintain. Lower final costs for modern pipelines result from J&L experience, continuing research, constantly improved techniques, and insistence on quality.

Leading pipeliners expect — and get — performance-proved products from their local Jones & Laughlin Supply Store or office.



The Sealdport® pressurized lubrication system in Rockwell-Nordstrom plug valves actually repairs itself. The lubricant gives a continuous new seating surface. Under pressure, the lubricant is a powerful seal between the body and the plug. Like self-sealing auto tires, this seal can't be permanently cut, scratched or damaged. Rockwell-Nordstrom plug valves offer dependability and economy. Ask your J&L man for a Rockwell-Nordstrom catalog.

Jones & Laughlin

SUPPLY DIVISION – Tulsa

If it's sold by J & L . . . .
It's the best available 106

Left, J&L Electricweld Line Pipe's lengths are uniformly round and line up end to end in perfect butt joints with uniform bevels for fast welding. The uniform high ductility of J&L Electricweld assures easier field bending. Descriptive literature is available from your local J&L man.

Taylor Forge welding fittings are backed by years of engineering and research. Here is an outstanding line of standard and special purpose fittings for pipeline use. The photo, taken at a pipeline station, shows the installation of Taylor Forge ells and flanges on first stage gas scrubbers. Your local Jones & Laughlin representative will be glad to give you illustrated literature on these quality welding fittings.

WHAT'S HAPPENING IN PIPE LINE CONSTRUCTION

By Donald G. DePugh, Construction Editor

Midwestern Plans to Begin Work Soon On 504-Mile Gas Main Line From Canada

As a result of the Canadian National Energy Board approving export requests of Trans-Canada Pipe Lines Ltd., Alberta & Southern Gas Company and Westcoast Transmission Company, several proposed pipe line projects in the United States are a step closer to reality.

Midwestern Gas Transmission Company announced that it plans to construct the 504-mile, 24-inch line from near Emerson, Manitoba, to Marshfield, Wis., this year. Midwestern received FPC approval of this project last year and will take 204 MMcf of gas daily from Trans-Canada to serve the upper Midwest area.

Trans-Canada will begin construction soon on its 1960 expansion program which includes a 50-mile, 30-inch extension from Winnipeg to Emerson, Manitoba, to supply Midwestern. Other facilities in Trans-Canada's $39 million program for the year will include eight new compressor stations in Saskatchewan, Manitoba and Ontario. Six of these will use gas turbine prime movers.

"Income of over $400,000,000 in American funds will be earned from the Emerson contract alone over the life of the permit," James W. Kerr, president of Trans-Canada stated.

Michigan Wisconsin Pipe Line Company will lay a 311-mile line from Marshfield to Appleton, Wis., to take gas from Midwestern.

Alberta & Southern Gas Company was authorized to export 3,826 billion cubic feet over a 25-year period to its owner company Pacific Gas & Electric Company. Pacific Gas & Electric and subsidiary, Pacific Gas Transmission would build a 1,000-mile, 36-inch line from the Canadian border to San Francisco. This project is still pending FPC and California Public Utilities Commission approval. Alberta Gas Trunk Line Co. and Alberta Natural Gas Co. Ltd., would build the 400-mile main line in Alberta and British Columbia to supply gas to PG&E.

Westcoast Transmission Company also will export more gas to the states.

It has been authorized to export an additional 152 MMcf of gas daily through Alberta & Southern pipe lines.

Niagara Gas Transmission Company was denied authorization by the board. Niagara planned to export to its affiliate, St. Lawrence Gas Co., to supply gas in Ogdensburg, N. Y. St. Lawrence has FPC approval to build a 75-mile line from the border to Ogdensburg and hopes a decision will be reversed by the board.

Canadian-Montana Pipe Line also received an okey to deliver gas to Montana Power Company in Montana.

Michigan Wisconsin Lets Contracts on 530 Miles

Contracts have been let by Michigan Wisconsin Pipe Line Company for construction of 530 miles of 24 and 30-inch gas pipe lines. R. H. Fulton & Co. will lay 270 miles in Texas, Oklahoma and Kansas, Bechtel Corporation will construct 120 miles in Illinois and Indiana, Somerville will build 80 miles in Michigan and Majestic Contractors has 60 miles in Illinois.

Michigan Wisconsin is awaiting FPC approval on the project.

El Paso Lets Contract To R. H. Fulton & Co.

El Paso Natural Gas Company has awarded a contract to R. H. Fulton & Co. for construction of 130 miles of 30-inch loop lines.

The company also has let contract to Bowden Construction Co., Delta Engineering Corporation, Fluor Corp., Fisher Contracting Co. and Western Pipe Line, Inc., on construction of 29,000 additional compressor horsepower.

Products Pipe Lines From Alberta to Chicago Planned

Plans are being considered by Pembina Pipeline Ltd., to build a pipe line system from Alberta to Chicago for transportation of natural gas by-products.

The system would include a main line and gathering facilities in Alberta and a main line from Alberta-Saskatchewan border to Chicago. The 2,000-mile project would cost in the neighborhood of $150 million.

Studies show that in two years about 92,000 barrels of liquids per day would be produced in Alberta.

To move the products to Chicago, Pembina formed a new company, Westalta Products Pipeline Ltd., to construct the 900-mile system in Alberta and another affiliate, Foothills Pipe Lines Ltd., would build and operate the 1,300-mile 16-inch line to the Midwest.

The proposals are before the Alberta Board of Public Utility Commissioners.

Generally a 48-inch pipe would present construction problems, but here it solves a major difficulty. Unable to move welding machine over swampy area near Everett, Wash., contractor Alton V. Phillips rode pipe rigs and welding generators on the large

water line. Vehicles traveled the wooden trestle to carry materials and equipment to the job. The 15,400-foot line will supply water to Everett.

CLEVELAND 320 TRENCHERS, digging in tandem, helped Panama, Inc. make up for time lost due to excessive rainfall on the 238-mile 30-inch Humble gas line from King Ranch to Clear Lake, Texas. Across the coastal plains the 320's, working singly, each averaged about a mile and a half of 6-foot-deep trench daily.

ON SMALLER DIAMETER LINES, the Cleveland Model 140 Trencher — shown at right digging a 38-mile gas extension in Idaho at well over 2 miles per day—has enjoyed a 30-year reputation among pipeliners for dependable low-cost production on jobs of all kinds, from field and gathering lines up through cross-country main lines up to 18" diameter.

Good Everywhere ®

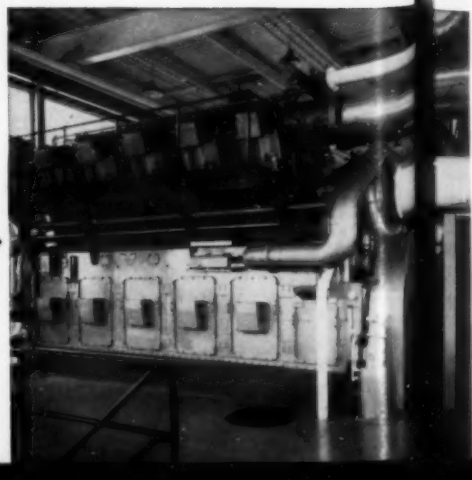
The CLEVELAND TRENCHER Co.

20100 St. Clair Avenue • Cleveland 17, Ohio

For more data on advertised products, use Readers' Service Cards, last page.

Background: One of three 2500 hp Type GMWA Cooper-Bessemer compressors at Winnipeg station.

Exterior view of Winnipeg compressor station of Trans-Canada Pipe Lines.



The three 2500 hp Type GMWA compressors at Winnipeg station.

Robert Jones, *General Manager, Cooper-Bessemer of Canada, Ltd., explains a vital project...*

Speedy building of Trans-Canada facilities provides gas for Canadian growth

Trans-Canada Pipe Lines is a great and growing Canadian enterprise. Its 2290-mile line carries the means for long-term, continuing benefits—new industries, new jobs, new purchasing power—spread from Vancouver to Labrador.

There is now an abundant gas supply for this growing nation, thanks to the speedy completion and dependable operation of Trans-Canada facilities. The station, shown here, at Winnipeg, Manitoba, equipped with three 2500 hp Cooper-Bessemer compressors, is a good example of this performance.

Cooper-Bessemer is proud of the part it has played in providing Trans-Canada with the dependable Winnipeg station and other Cooper-Bessemer powered stations *ahead of schedule*. Find out how we can help meet *your* needs in modern compression and power facilities.

BRANCH OFFICES: Grove City • New York • Washington • Gloucester • Pittsburgh Chicago • Minneapolis • St. Louis • Kansas City • Tulsa • New Orleans • Shreveport Houston • Greggton • Dallas • Odessa • Pampa • Casper • Seattle • San Francisco Los Angeles

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TR

DETECTOR

locates pipeline holidays and electrical contacts underground

OSCILLATOR

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Problems caused by underground pipe contacts with other lines and holidays in the protective coating can be solved by the Tinker and Rasor Pearson-type Detector which locates underground shorts in coated pipelines.

This completely transistorized unit finds trouble spots underground without the necessity of uncovering the pipe. Working in tandem, a two man crew can inspect an entire line, locating coating breaks, contacts with other lines and mapping the entire line.

The TR Underground Holiday Detector operates on a 12 volt automobile battery. It generates a 15 watt, 750 cycle, stable A.C. audio-frequency signal on a pipeline. Two 750 cycle resonate filters in the receiver reject unwanted signals.

Write today for technical data and bulletin.

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Atlantic Lets Contract To Williams Brothers Co.

Contract for 45 miles of 20-inch has been awarded to Williams Brothers Company by Atlantic Seaboard Corporation. The line will run from Terra Alta to Seneca station in West Virginia.

Manufacturers Light Plans To Lay 87 Miles of 20-Inch

Manufacturers Light and Heat Company has filed an application with the Federal Power Commission for construction of 87 miles of 20-inch gas lines in Franklin, Adams, Fayette and Greene counties Pennsylvania. The cost will be about $6.8 million. Company also plans to abandon 88 miles of 6-inch line and 131 miles of 8-inch in Pennsylvania.

Continental-Husky Announce Joint Products Line Proposal

Continental Pipe Line Company and Husky Oil Company plan to construct an 85-mile, 6-inch, products pipe line in Montana. The line will extend from Helena to Great Falls; it will connect with the Yellowstone Pipe Line Company system at Helena to move products to Great Falls. The line will be owned by Continental and Husky and built and operated by Continental.

Kenai Pipe Line Company Formed to Build Crude Line

Standard Oil Company of California has formed a new company, Kenai Pipe Line Company, to build a pipe line from Swanson River Unit and Soldotna Creek Unit to Nikiski on Cook Inlet in Alaska.

The $4 million project includes a 20-mile, 8-inch crude line and a marine tanker loading terminal at Nikiski.

Mississippi River Fuel Corp. Files Application with FPC

Mississippi River Fuel Corporation has filed an application with the FPC requesting permission to lay 20 miles of 12-inch gas lateral lines. The $3 million project would include 2 miles of 4-inch, a 2,500 hp station; all facilities will be constructed in developing the St. Jacob field in Madison and St. Clair counties, Illinois.

Buckeye Plans 54 Miles of Crude Pipe Line Extension

Plans for 54 miles of crude line in Michigan have been announced by Buckeye Pipe Line Company. The project will consist of a 22-inch extension from Toledo to Samaria, Mich., and a 16-inch line from Samaria to refineries in Trenton and Detroit.

Buckeye will convert some smaller crude line to Detroit to products lines. Cost of construction program is about $4 million.

Expansion Project Announced by Texas Gas

Texas Gas Transmission Corporation has filed an application with the FPC seeking authorization for construction of 80 miles of pipe line and an addition of 5,820 horsepower at existing stations. The $8 million project would provide greater operating flexibility on the company's system and greater assurance of continuous service in meeting certificated service.

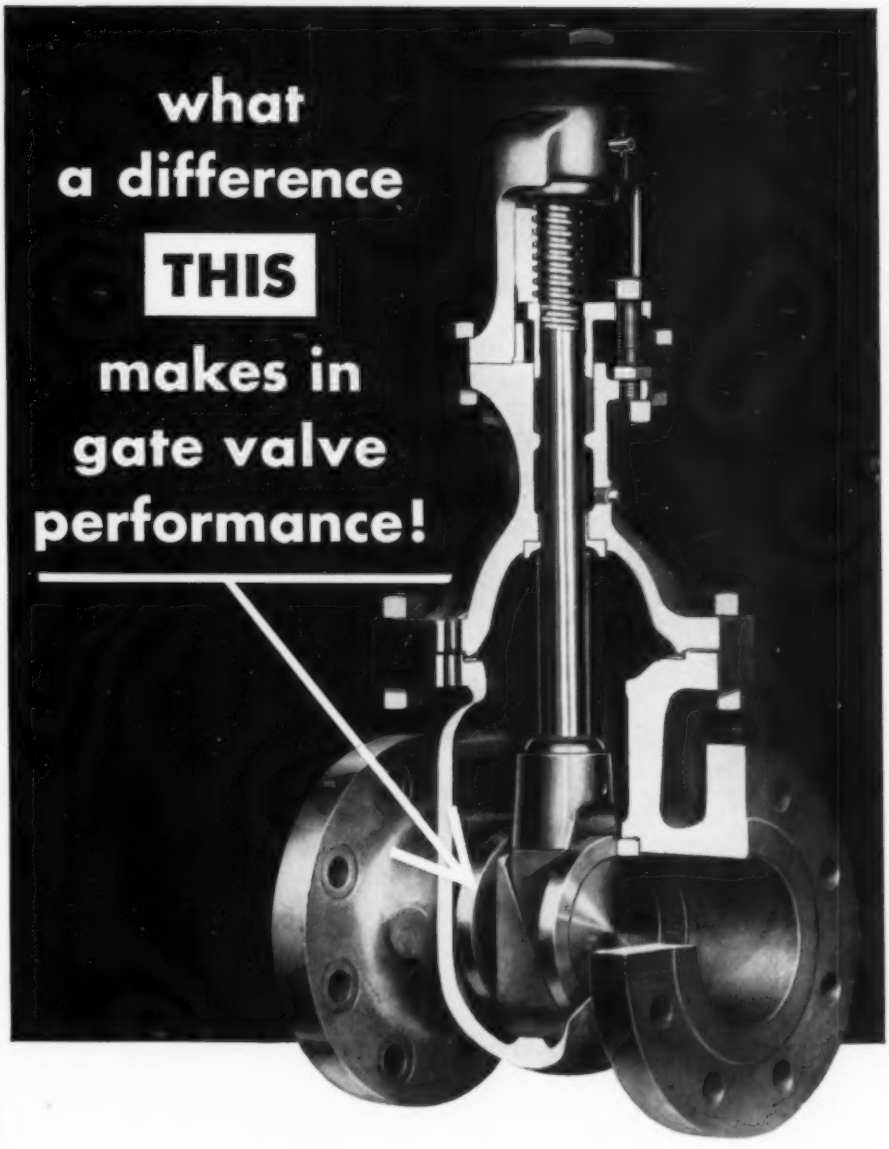
Texas Gas would lay 24 miles of 30-inch and approximately 56 miles of 12-inch. The 30-inch section would be between Eunice and Bastrop, La. The 12-inch portion will be laid from a point near the Wilford Storage field on the Slaughters-Terre Haute system to the Hardinsburg-Bedford 16-inch line.

Compressor additions would include 1,320 hp at Lafayette, 2,500 at Covington, 2,000 at Calvert City and the installation of turbochargers on the two 880-hp engines at Lafayette, increasing their hp to 1,320.

FPC Examiner Approves St. Lawrence Application

St. Lawrence Gas Company received approval from Federal Power Commission examiner to import Canadian gas. The plan was accepted over a proposal by New York State Natural Gas Company to serve the same area with domestic gas.

St. Lawrence, a subsidiary of The Consumers' Gas Company of Canada, would build a 75-mile gas line from the Canadian-United States border to Ogdenburg, N. Y. St. Lawrence would take gas from Niagara Gas Transmission Company at the border. Meanwhile, the Canadian National Energy Board denied Niagara Gas a 20-year export license.



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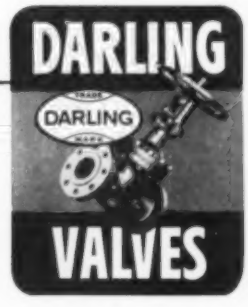

For more data on advertised products, use Readers' Service Cards, last page.

MUDDY GOING IN MOSCOW

Moscow, *Kentucky*, that is. That's where our photographer had the muddiest assignment of his career. But his problems were trifling compared to those of the men who had the job of laying 30-in. pipe for Trunkline Gas Company. For them, hipboots were standard dress. Fortunately, men and machines proved to be hardy "mudders," and the line went through.

The project was Panama, Inc.'s Spread Two, extending south from Clinton, Kentucky to the vicinity of Union City, Tennessee. Bethlehem Line Pipe was used on this and other spreads in Trunkline's current program, which calls for 895 miles of looping lines and an extension of their main line to the Michigan-Indiana border.

TRENCH OR DAM? Mud wasn't the pipeliners' only problem. Heavy rains soaked the earth, causing numerous cave-ins.

THAT'S MORE LIKE IT! The going was a lot smoother on this Trunkline spread near Leland, Mississippi. Here, too, both Panama, Inc., and Bethlehem pipe were on the job.

Bethlehem Line Pipe from ½ to 42 in. OD

Bethlehem supplies line pipe in all sizes, including continuous buttweld (½ in. through 4½ in.), electric resistance-weld (5⅝ in. through 16 in.), and electric fusion-weld (18 in. through 42 in.). In the larger diameters, Bethlehem is now able to furnish walls up to ¾ in. thick.

Need line pipe? Just call our nearest sales office.

for strength
... economy
... versatility

Steel

THERE'S MUD IN ROME, TOO! Rome, New York, that is. Pipeliners are shown here wrestling with Bethlehem 6⅝-in. OD electric resistance-weld pipe for Buckeye Pipe Line Company's jet fuel line to Griffiss Air Force Base.

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Export Distributor: Bethlehem Steel Export Corporation

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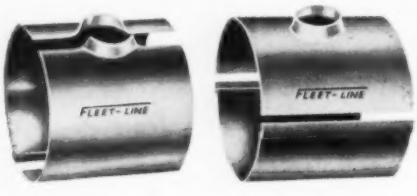
REDUCERS: Concentric and eccentric. Nominal pipe sizes 1" to 30", ASA B16.9, ASTM A234. Schedules 10 to 160, stainless steel, and other alloys. Special lengths and sizes.

SADDLES: Conventional, and for pressure vessel heads. Nozzle sizes from ¼" to 24". Fleet-Line saddles weld neatly into place in much less time, and with much less welding rod.

Full encirclement saddles.



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PROPOSED PIPE LINE CONSTRUCTION

Here in convenient summary form is Pipe Line Industry's listing of company, line size, length, service, location and project status.

U. S.

Algonquin Gas Transmission Co., Boston, 25 miles, 20-inch; 8 miles, 8-inch, gas, and 12,000 hp addition in Massachusetts. $6 million, before FPC.

Anchorage Gas Corp., Houston, 165 miles, 12-inch, gas, Kenai to Anchorage, Alaska, $15 million, planned.

Arkansas Industrial Pipeline Corp., Shreveport, 130 miles, 18-inch, gas, Perla-to-Helena, Ark., $9 million, planned.

Arkansas Louisiana Gas Company, Shreveport, La., 58 miles, 2-6-inch, gas, planned.

Atlantic Seaboard Company, Charleston, W. Va., 43 miles, 20-inch, gas, main, Seneca to Terra Alta, W. Va., $25 million, contract let to Williams Bros. Co.

Belle Fourche Pipeline Co., Casper, Wyo., 103 miles, 8-inch, crude, Fiddler Creek field to Lance Creek, Wyo., and branch lines from North Donkey Creek field to Rozet and Miller Creek fields, $2¾ million, before Wyoming Public Service Commission.

Buckeye Pipe Line Co., New York, 54 miles, 16-22-inch, crude, main lines from Toledo to Trenton, and Detroit, Mich., $4 million, planned.

Carolina Pipeline Company, Columbia, S. C., 85 miles, 8-inch, gas, in South Carolina, $5 million, before FPC.

Coastal States Gas Producing Co., Corpus Christi, Texas, 60 miles, 10-inch, gas, gathering, La Salle and Frio counties, Texas, before FPC.

60 miles, small diameter, gas gathering line, to tie in with system under construction and extend to Pearsall County, Texas, planned.

25 miles, gas, Associated Gas & Oil Co. field to South-Tex Corp., processing plant west of Corpus Christi, Texas, planned.

37 miles, gas gathering in Brown, Eastland, Comanche and Erath counties, Texas, planned.

Coastal Transmission Corp., Houston, 81 miles, 3 to 10-inch, gas, laterals; 5,500 hp in stations at Port Lavaca, Texas, and Eunice, La., and additional 1,500 hp at Robstown, Texas, $6.2 million, before FPC.

Colorado Interstate Gas Co., Colorado Springs, 140 miles, 34-inch, gas, Green River, Wyo.-to-Provo, Utah; 109 miles, 26-inch, Texas Panhandle to southeastern Colo., 136 miles, 34-inch, southeastern Colorado-to-Pueblo, Colo.; 107 miles, 30-inch, Pueblo-to-Denver, $91 million, before FPC.

Colorado Oil & Gas Corp., Denver, 400 miles, gas, from Gubik field to Fairbanks, Alaska, planned.

Columbia Gulf Transmission Co., Houston, 12.8 miles, 6 and 20-inch, gas, loop line in Louisiana, $730,000, authorized.

Continental Pipe Line Co. (joint venture with Husky Oil Co.), Ponca City, Okla., 85 miles, 6-inch, products, Helena to Great Falls, Mont., planned.

East Coast Pipeline Co., 90 miles, 12- to 24-inch, products, Linden, N. J. to Suffolk County, N. Y., $25 million, planned.

El Paso Natural Gas Company, El Paso, 244 miles, 30-inch, Permian-San Juan loops, 108 miles, 20-inch, field feeder lines, contract let on 304 miles to R. H. Fulton and Western Pipe Line, Inc.

69,240 hp in new and existing stations in Texas, Oklahoma, New Mexico and Utah, planned.

400 miles, 34-inch, Salt Lake City, Utah, to California border, before FPC.

Equitable Gas Company, Pittsburgh, Penn., 11.7 miles of storage pipe line and other facilities, $2,091,430, authorized.

12½-miles, 16-inch, paralleling existing system in Harrison and Marion counties, W. Va., authorized.

Farmers Union Central Exchange, St. Paul, Minn., 200 miles, 8-inch, products, Glendive, Mont. to Minot, N.D., planned.

Gillette Pipeline Co., Cheyenne, Wyo., 103 miles, crude, from Dead Horse Creek field to Casper, Wyo., planned.

Goliad Corp., Houston (Joint venture with **Union Oil Co. of Calif.**), 85 miles, LPG, Kaplan, La. to Baton Rouge, extraction plant at Kaplan and fractionation plant at Baton Rouge, $12 million, planned.

Great Lakes Pipe Line Co., 58 miles, 8-inch, products, from Grinnell to Waterloo, Iowa, planned.

Great Northern Railway, St. Paul., 110 miles, crude, fields in Burke and Bottineau counties to Minot, N. D., $3½ million, before Public Service Commission.

Gulf Resources, New York, 125 miles, gas, gathering system, from Lopena area in Zapata County to a point in La Salle County, Texas, planned.

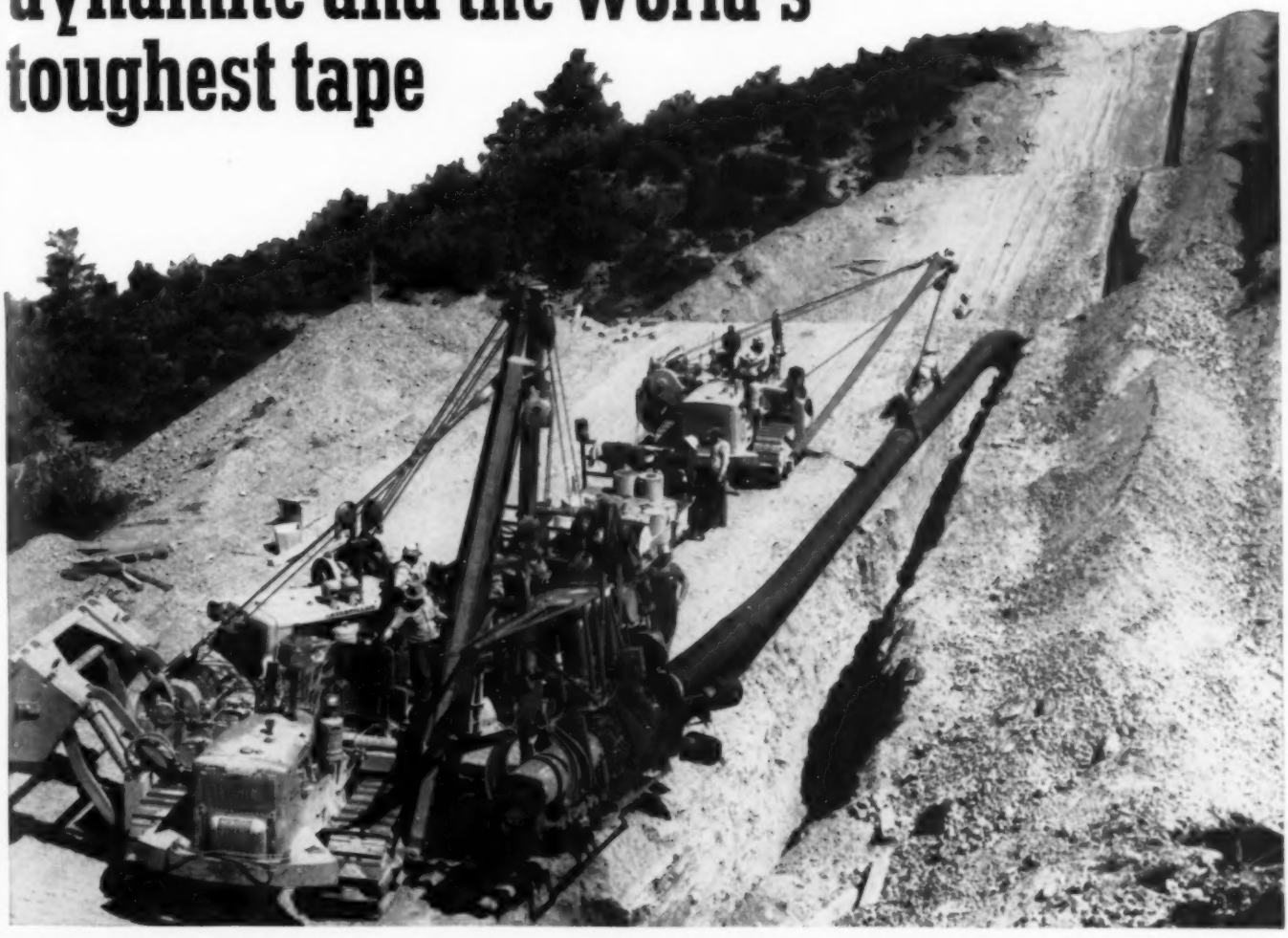
Hope Natural Gas Co., Clarksburg, W. Va., 45 miles, gas, from West Virginia to Pittsburgh area, planned, 20 miles, 24-inch, gas, in Wertzel and Monongalia counties, W. Va., authorized.

Houston Texas Gas & Oil Corp., St. Petersburg, Fla., 199 miles, 2 to 6-inch, gas, laterals; 20,000 hp in five new stations; $12 million, before FPC.

Humble Pipe Line Company, Houston, 63 miles, 8-inch, crude, and gathering system Sacatosa field, Maverick County to Pearsall, Texas, planned.

Continued on Page 66

Jobs this rough need mountain climbers, dynamite and the world's toughest tape



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Before you plan your next job, we'd like to tell you more about Polyken Extra-Strength #960. Call the Polyken distributor nearest you, or write Polyken, 309 West Jackson Blvd., Chicago 6, Illinois.

Polyken Tapes can be applied swiftly, easily, effectively, even under extreme conditions. This mountain-country coating went on with flat-country simplicity. That's why more contractors and pipeline managers are specifying Polyken.

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PROPOSED CONSTRUCTION

continued

Iron Ranges Natural Gas Co., 115 miles, gas, from Itasca and St. Louis counties along route of Mesabi range from Grand Rapids to Aurora, Minn., $5 million, FPC authorization.

60 miles from Duluth to Silver Bay, Minn., FPC authorization.

Kansas-Nebraska Natural Gas Co., 15 miles, 12-inch, gas, loops and 4,800 additional hp at new and existing stations, $1.5 million, FPC authorization.

Laclede Gas Co., St. Louis, 107 miles, 24-inch, gas, Hallsville to St. Louis, Mo., planned.

Manufacturers Light and Heat Company, Pittsburgh, 87 miles, 20-inch, gas, in Franklin, Adams, Fayette and Green counties, Pa., $7 million, before FPC.

Matador Pipe Line Corp., Denver, 175 miles, crude, from Bottineau, Burke and Renville counties, N. D., to Cromer, Man., Canada, $4 million, proposed.

Michigan Wisconsin Pipe Line Co., Detroit, 311 miles, gas, main, Marshfield to Appleton, Wis., authorized.

66 miles, 30-inch, loops, Indiana, Illinois, and Michigan, authorized.

342 miles, 24-inch, gas, loops, Kansas, Missouri, Illinois, and Iowa, before FPC.

123 miles, 30-inch, loops, between Sandwich, Ill and Big Rapids, Mich., before FPC.

37 miles, 6 and 12-inch lateral loops in Wisconsin, before FPC.

29 miles, 30-inch, loops, Illinois, Indiana, and Michigan, 3,000 hp. station, Janesville, Wis., before FPC.

Two 2,000 hp units at Meade, Kansas; one 2,000 hp unit at Havensville, Kansas, before FPC.

Mid-America Pipeline Co., Tulsa, 2,000 miles, 6-10-inch, LPG, from Texas-New Mexico to St. Paul, Minn., and Milwaukee, Wis., areas, $71 million, contract let to **Williams Brothers Company**.

Midwestern Gas Transmission Co., Houston.

504 miles, 24-inch, gas, from Minnesota-Canada border near Winnipeg to Marshfield, Wis., $52 million, FPC, authorization.

Mississippi River Fuel Corp., St. Louis, 20 miles, 12-inch, 3 miles, 4-inch, gas, 2,500 hp station, to develop underground storage reservoir at St. Jacobs field in Madison and St. Clair counties, Ill., $3 million.

Mississippi River Transmission Corp., (subsidiary Mississippi River Fuel), 115 miles, 24-inch, gas, southeast Missouri to St. Louis County, planned.

Natural Gas Gathering Co., Inc., (joint venture with Gulf Resources, Inc.) gas gathering facilities in Zapata and Starr counties Texas, before FPC.

Natural Gas Pipeline Company, Chicago. 151 miles, 36-inch, gas, loops, between Ford County, Kansas and Joliet, Ill. and 180 miles, 24-inch, main, from Minneola, Kan. to Kiowa County, Okla., $31 million, before FPC.

New Haven Pipeline, Inc., products line, New Haven, Conn. to Springfield, Mass., $2.5 million, planned.

Northern Illinois Gas Co., Aurora, Ill., 75 miles, 30-inch, gas, from underground storage at Troy Grove to LaGrange, Ill., $10 million, planned.

Northern Natural Gas Company, Omaha.

171 miles, main line extensions, 66 miles, main loops, 139 miles, branch lines, 6,000 hp additions, to extend system from Minneapolis to Duluth-Superior area, $25.7 million, contracts let on 315 miles to Williams Bros. Co. and R. H. Fulton & Co.

46 miles, main line extensions, 191 miles, loops, 1,767 miles, branch lines, and 45,400 additional hp, in Iowa, Minnesota, South Dakota, Nebraska, Wisconsin and Illinois, $76.7 million, FPC authorization.

37 miles, 30-inch, Bushton compressor station to Otis field, Kansas, 7,000 additional hp at Bushton, and development of underground storage facilities at Otis field, $20 million, before FPC.

Ohio Fuel Gas Co., 59 miles, gas, 4-24-inch main lines, in Belmont, Carroll, Cuyahoga, Fairfield, Logan, Lorain, Marion, Muskingum, Stark and Wayne counties, Ohio, $5.1 million, planned.

Oklahoma Resources Development Co., Oklahoma City, 170 miles, 12-inch, gas, Oklahoma City to Harrah and Muskogee, Okla. and 130 miles, 4-12-inch lateral, planned.

Pacific Gas & Electric Co., San Francisco, 296 miles, 36-inch, gas, from Malin,

Continued on Page 68

BUT Oil Gaging Needs Precision Equipment from W. H. Curtin & Co.

Complete stocks of Petroleum Gaging Equipment meeting all API and ASTM specifications are maintained for immediate delivery by W. H. Curtin & Co. Curtin oil testing centrifuges and tubes, thermometers and hydrometers, as well as all other gaging equipment, are of the finest quality and constructed for a long lifetime of use in field or laboratory. Replacement parts are readily available for all equipment. On your next order, specify the high quality gaging equipment you can rely on from W. H. Curtin & Co.

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Four Corners Pipe Line is the first of such a length ever designed for operation from a single, central control station at its Los Angeles terminal.

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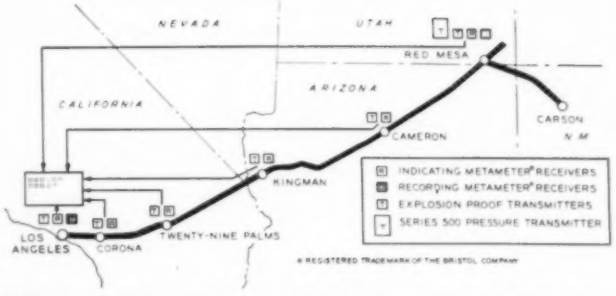
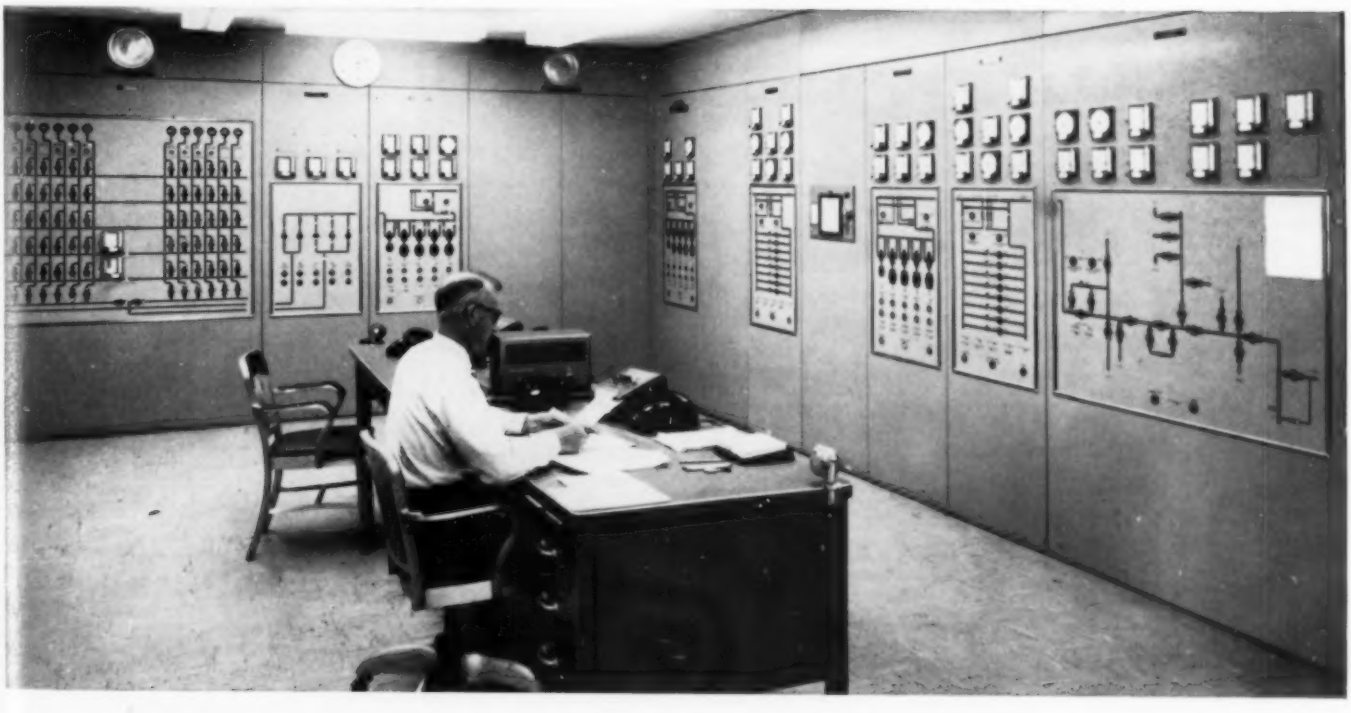


Miniature Bristol Telemetering Recording and Indicating Receivers, on panel shown below, give dispatcher instant instrument readings from points up to 600 miles distant along Four Corners Pipe Line. (See map.)



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PROPOSED CONSTRUCTION

continued

Ore., to Antioch, Calif., southern section of line from Canada to California, before California Public Utilities Commission.

10 miles, 20-inch, Pittsburg to Walnut Creek, Calif. planned.

2.7 miles, 16-inch, Marin County, Calif., planned.

4.4 miles, 16-inch, Sonoma County, Calif. planned.

7.5 miles, 16-inch, south of Fresno, Calif. planned.

Pacific Gas Transmission Co., San Francisco, 614 miles, 36-inch, Kingsgate B.C. to Malin, Ore., northern section of Canada to California line, before FPC.

Panhandle Eastern Pipe Line Co., Kansas City, 305 miles, 30-inch, 40 miles, 26-inch, gas, loops, and 43,000 hp, and gathering facilities, $60 million, before FCP.

Peoples Gas Light & Coke, Chicago, 29 miles, 36-inch, gas between North Shore and Calumet stations, planned.

Peoples Gulf Coast Natural Gas Pipeline Co., Chicago. 371 miles, 30-inch, loops, and 45 miles, gas laterals, 6,700 hp in Victoria County, Texas, $43.5 million, before FPC.

Rio Gas Gathering Co., San Antonio, 97 miles, 3 to 8-inch, gas gathering, South Texas, to supply gas to El Paso Natural Gas Company, planned.

Rocky Mountain Natural Gas Company, 65 miles, gas, southwestern Colorado to serve Delta, Orchard City and Montrose, Colo., planned.

Seadrift Pipeline Corporation, 108 miles, gas, main, from Union Carbide's plant at Seadrift to Humble Oil & Refining Company's King Ranch gas plant, planned.

Southern California and Southern Counties Gas Cos., Los Angeles, 93 miles, 34-inch, California-Nevada border to Newberry, Calif., approved.

Standard Oil Company of California, 22 miles, 8-inch, crude, Kenai Peninsula to Nikiski, Alaska, $4 million, considered.

St. Lawrence Gas Company, Inc., Ogdensburg, N. Y., 75 miles, gas, main, United States-Canadian border to Ogdensburg, N. Y., $3.4 million, FPC examiner approval.

Tennessee Gas Pipeline Co., Houston, 155 miles, 30 and 36-inch loops, in Ohio, Pennsylvania and New York, 72 miles of gathering lines and 31,300 hp in five stations, $43 million before FPC.

158 miles, 36-inch, gas, loops in Mississippi and Louisiana, FPC authorization.

21 miles, 16-inch, 2 miles, 12-inch, gas, Louisiana coast, Vermilion blocks 46 and 64, $3 million, before FPC.

Tennessee Oil Refining Company, Houston, 6 miles, 4-inch, products, Palacios, Texas, to company's main line; 16-miles, gas gathering system, near Palacios, contract let to **Sheppard-Geiger Construction Co.**

Texas Eastern Transmission Corp., Shreveport, La., 212 miles, 20 to 36-inch, gas, and 3,300 hp station, in Pennsylvania, New Jersey, New York and Mississippi, $46 million, before FPC.

90 miles, LPG, Lebanon to Lima Ohio, planned.

350 miles, 24-inch, coal slurry, Wes Virginia to New York, considered.

Texas Pipe Line Company, Houston, 4 miles, 6-inch, LPG, Franklin County t Nettleton, Texas, planned.

Transcontinental Gas Pipe Line Corporation, Houston, 129 miles, 30 and 36-inch loops; 53 miles of laterals, and additional horsepower capacity, in Texas, Louisiana, Alabama, Georgia, North Carolina, Virginia, Pennsylvania an New Jersey, $53 million, FPC examine approval.

211 miles, 36-inch, and 69 miles, 30 inch, loops and additional 32,040 hp in Texas, Louisiana, Mississippi, Alabama, Georgia and South Carolina, $5 million, before FPC.

13 miles, 24-inch and 18 miles, 20 inch loops, Louisiana, FPC authorization. 14 miles, 16-inch laterals, 1-mile, 12-inch lateral, Louisiana, $2.1 million, FPC authorization.

29 miles, 20-inch, gas, and 2,500 hp, in South Texas to take gas from South Texas Natural Gas Gathering Co., $2.4 million, before FPC.

Transwestern Pipeline Company, Houston, pipe line facilities to cost $5.4 million to make available additional gas reserves for the line presently under construction, before FPC.

Trunkline Gas Company, Houston, 252 miles, 30-inch loops, and 140 miles, laterals, between Longville, La., and Tuscola, Ill., $45 million, before FPC.

Underground Storage & Exploration, Upper Darby, Penn., 394 miles, 12-inch

Continued on Page 70

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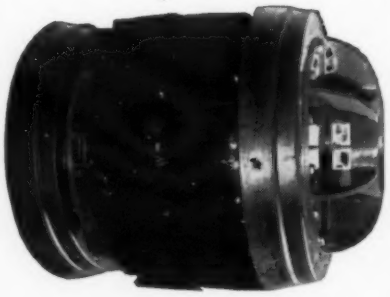

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PROPOSED CONSTRUCTION

continued

LPG, from Moundsville, W. Va. to Newark, N. J., $9 million, approved.

95 miles, 6-8 inch, laterals to Mauch Chunk, Penn., and to Philadelphia, planned.

United Gas Pipe Line Co., Shreveport, La., 59 miles, 36-inch, gas, lateral between Bastian Bay field and Plaquemines Parish, La., before FPC.

Valley Gas Transmission, Inc., Houston, 55 miles, 3 to 8-inch, gas, gathering, in Hidalgo, Brooks, Starr and Jim Wells counties, Texas, $15 million, before FPC.

International

ACT Oils, Ltd., Montreal, 400 miles, crude, Dawson Creek, B. C., to Bella Coola, B. C., before B. C. government.

Alberta Gas Trunk Line Company, 386 miles, 26-36-inch, gas, main, Berland River area, Alberta, to Alberta-British Columbia border; and 235 miles, 8-18-inch, gas, gathering, Alberta, $100 million, Alberta Oil and Gas Conservation Board, approved.

Alberta Natural Gas Company (Jointly owned by Westcoast Transmission Co. and Alberta & Southern Gas Co. Ltd.) 110 miles, 36-inch, gas, Alberta border to British Columbia-Idaho border, supply gas to Pacific Gas & Electric Co., $40 million, planned.

Arabian American Oil Company, New York, 63 miles, 30-inch, crude, from Khursaniyah station to Ras Tanura, planned.

Barnabos Group (Italian Interests), crude line from Venice, Italy to Insbruck, Austria, with extension to Munich, Germany, planned.

Bituminous Oil Pipeline Co., Calgary, 250 miles, crude, from Athabasca tar sand plant in northeastern Alberta to Edmonton, approved.

Brazilian Government, Rio de Janeiro, 300 miles, 12-inch, crude, Rio de Janeiro to Belo Horizonte, planned.

British American Oil Co., Ltd., Toronto, 125 miles, gas, Pincher Creek fields to Calgary, Alta., before Alberta Public Utilities Board.

Burmah Oil Co., Ltd., 850 miles, crude, 20 inch, from Nahorkatiya to Calcutta, India.

Cartier Gas Corp. (St. Maurice Gas, Inc., and Consumers Gas Co., Toronto), 170 miles, gas, Montreal to Quebec City, planned.

Consolidated Gathering Systems, Ltd., Calgary, 198 miles, crude, Sturgeon field to Edmonton, planned.

Creole Petroleum Co., 44 miles, 12-30-inch, gas, Bachaquero to Tia Juana, Venezuela, planned.

Development and Resources Corp., 70 miles, 8 inch, gas, from Agha Jari oil field to Ahwaz, Iran, planned.

Entre Nazionali Idrocarburi, Rome, Italy, crude, from Qum field in Iran to the Mediterranean Sea, considered.

Esso Standard Libya, 100 miles, 30-inch, crude, Zeltan oil field to Gulf of Sirte coast, planned.

Foothills Pipe Line, Ltd., 500 miles, 12 to 16-inch, LPG, from Alberta to Pacific Coast, $80 million, considered.

Foothills Pipe Lines Ltd., 1,300 miles, LPG, from Alberta-Saskatchewan border to Chicago, tie-in with Westalta Products Pipeline proposed system in Alberta, $100 million, before Alberta Board of Public Utilities Commissioners.

Gases Naturales de Colombia, S.A., 140-mile, 10-inch, gas, Cicuco field to Barranquilla, Colombia, planned.

Hydrocarbons Pipeline, Ltd., Winnipeg, Manitoba, 880 miles, 6-8 inch, products, from Edmonton to Winnipeg, $35 million, partial authorization.

Independent Pipe Line Co., 2,019 miles, 34-36-inch, crude, Edmonton to Montreal, 23,000 pump horsepower, $395 million, before Borden Commission.

Interprovincial Pipe Line Company, 350-mile extension from Toronto to Montreal, looping line from Edmonton to Toronto, crude, $240 million, considered.

Additional horsepower in four new stations and several existing stations, $9.3 million, planned.

Continued on Page 72

This is one of the Deep Groundbed installations on the Houston Texas Gas and Oil Corporation's pipe line. The Deep Groundbed installation appears in the background. The Rectifier is mounted on the pole in the foreground.

CPS offers . . . TURNKEY PACKAGED CATHODIC PROTECTION

An outstanding . . . turnkey packaged cathodic protection . . . installation was recently completed by CPS for the Houston Texas Gas and Oil Corporation on their 1600 mile pipe line from Baton Rouge, Louisiana to Miami, Florida. The cathodic protection was completed on the entire line within six months after the construction program was final.

As a corrosion engineering firm . . . CPS offers a client . . . turnkey packaged cathodic protection . . . for any protection job regardless of size. CPS will advise a client on all phases of design, plus the selection and installation of all materials needed to complete an overall corrosion mitigation program.

Contact CPS . . . let their experienced staff of engineers quote you on a turnkey packaged cathodic protection program. Your inquiry will save you money.

A copy of the paper entitled "Packaged Cathodic Protection Of The 1600 Mile Taped Coated Pipe Line to Florida" prepared by E. P. Doremus and Ralph B. Pass will be mailed to you upon request.

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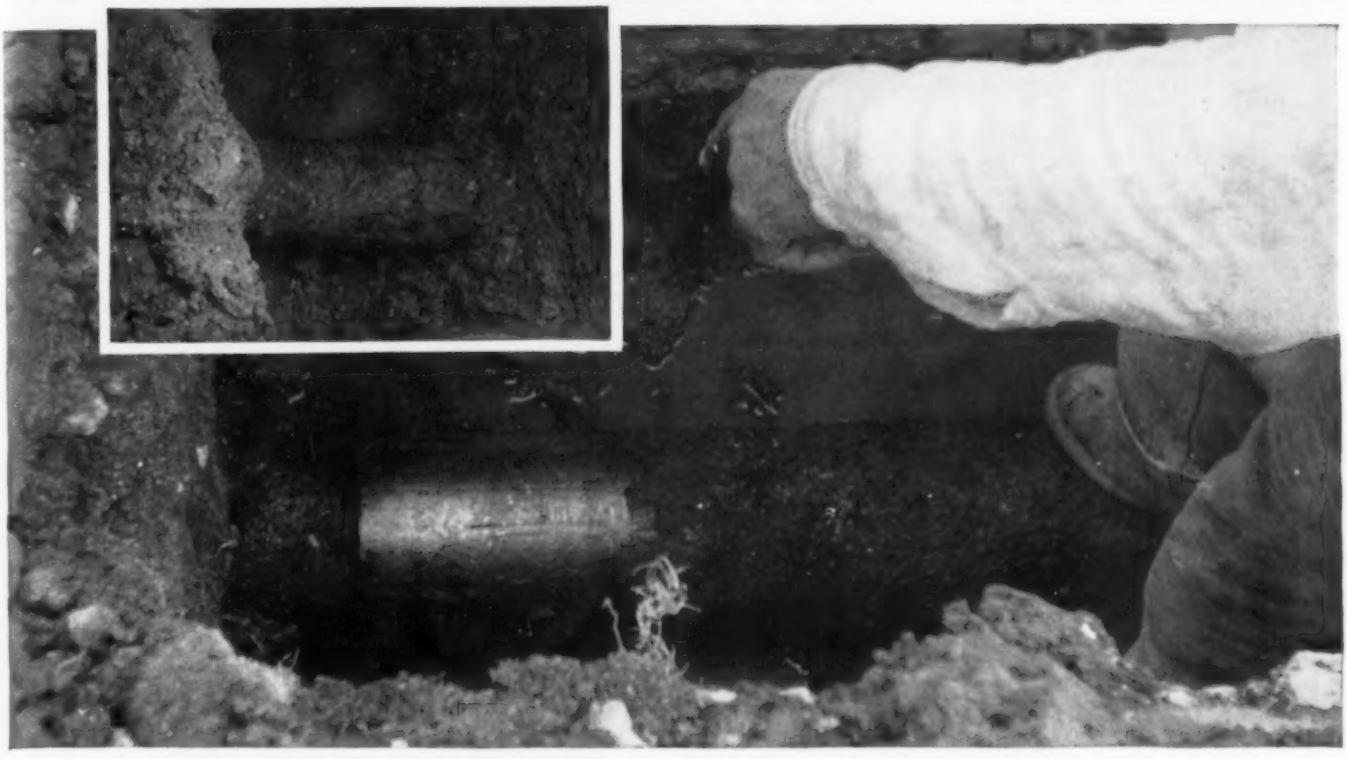
17-YEAR PROTECTION RECORD!



Year After Year...More Evidence Proving That TAPECOAT® Adds Years of Service Life to Gas Lines Underground or Under Water

Right across the country, TAPECOAT installations prove that you get more for your money when you measure pipe protection with a calendar.

Since this cost-cutting coal tar coating in tape form was first introduced in 1941, it has demonstrated its ability to withstand severe conditions underground or under water. TAPECOATED lines dug up after 17 years of service show no signs of deterioration on the pipe.

Typical is the experience of a utility in a coastal area. For a thorough trial, this company applied TAPECOAT in areas where severe corrosive conditions were known to exist. The lines were dug up this year and, after years of service under severe conditions such as brackish waters and corrosive soil, the pipe showed no signs of corrosion, proving the quality of TAPECOAT protection.

In terms of preventive maintenance and replacement costs, performances like this emphasize the most important consideration in buying protection. Remember, TAPECOAT is a hot-applied coal tar coating in tape form—designed for lasting protection on pipe, pipe joints, service connections, mechanical couplings, fittings, insulated lines, tanks, tie rods, and other steel surfaces vulnerable to corrosion.

TAPECOAT comes in rolls of various widths and is available in asphalt. Where primer is desired, specify TC Primecoat, the compatible coal tar primer.

A TAPECOAT sales and service engineer is always available to help you on any corrosion problem. Write for complete details today!

The TAPECOAT *Company*

ORIGINATORS OF COAL TAR COATING IN TAPE FORM

1537 Lyons Street, Evanston, Illinois

For more data on advertised products, use Readers' Service Cards, last page.

PROPOSED CONSTRUCTION

continued

Island Transmission Company Limited, Nanaimo, B.C., 25 miles, 10-inch, gas, from point near Vancouver, B.C. to Vancouver Island, 67 miles, 10-inch, laterals to Victoria and Nanaimo, B.C., $14 million, appeal before British Columbia Public Utilities Commission.

Magna Pipeline Co., 25 miles, 4-inch, gas, Vancouver, B.C. to Vancouver Island, $14 million, approved by Public Utilities Commission over Island Transmission Co. proposal.

Mid-Continent Pipe Lines, Ltd., 1500-mile, 30-inch crude, Edmonton to Chicago, planned.

Naphtha Israel Oil Co., 75 miles, 6-inch, gas, Rosh-Zohar field to Ashdod Yam on Mediterranean planned.

National Iranian Oil Co., 146 miles, 6 inch, crude, from Azna to Isfahan, Iran, $5 million, planned.

1000 miles, 38 inch, crude, from central Iran to the Turkish Mediterranean coast, considered.

500 miles, 8-inch, products, Teheran to Meshed, Iran, contract let on 250 miles to Williams Bros. Co.

Northern Alberta Pipe Lines, Ltd., Edmonton, Alta., 110 miles, 10-inch, gas, main, Lac La Biche to Edmonton, $3 million, planned.

Peace River Oil Pipe Line Co., Ltd., 70-mile, crude, Swan Hills to Iosegun Junction, approved.

230 miles, 8-inch, crude gathering, from fields in northeast British Columbia to Dawson Creek, B. C., and Grande Prairie, Alta., and to existing lines at Sturgeon Lake, $8.5 million, authorized.

Pembina Pipe Line, Ltd., Edmonton, 1,200 miles, LPG, from Alberta gas fields to eastern Canada, planned.

Petroleos Mexicanos, 4, 6 and 8-inch, products, Mexico City-Puebla to Cuernavaca, planned.

8-inch, products, and 12-inch, gas, Torreon to Chihuahua, to be built in 1960.

12-inch, products, Minatitlan to Puebla and Mexico City, construction to start in 1960.

Products, Guadalajara to Tepic, planned.

Products, Aguascalientes to Zacatecas, planned.

6-inch, products, Guaymas to Ciudad Obregon, considered.

8-inch products, Guaymas to Hermosillo, considered.

8-inch, gas, Tierra Blanca to Veracruz, to be built in 1960.

14-inch, gas, Mexico City to Salamanca, construction to start in 1960.

Gas, Ciudad Carmen to Ciudad Pemex.

8-inch, crude Comalcalco to Minatitlan, to be built in 1960.

Crude, Minatitlan to Salina Cruz, contingent on proposed refinery on Pacific Coast.

Pipelines of Puerto Rico, Inc., 95 miles, 8-inch, products, Penuelas to San Juan, Puerto Rico, approved.

Quebec Gas Transmission Lines Inc., Montreal, 300 miles, gas, main, Quebec to Montreal, planned.

Rangeland Pipe Line Company Limited, 111 miles, 8-inch, crude, southeastern Alberta to Calgary, $3 million, planned.

Saskatchewan Power Corp., 179 miles, 4-6-8-inch, gas, planned.

Societa Nazionale Metanodotti, 650 miles, 18-inch, crude, Genoa, to Milan-Cremona-Torino, Italy, and Aigle, Switzerland, with extensions to Karlsruhe and Munich, Germany, planned.

Societe d'Etude du Pipe Line Sud-European, Paris, 419 miles, 30-inch, crude, port of Lavera to Strasbourg, with lateral extending 40 miles to Karlsruhe, Germany, approved by French cabinet.

Standard-Vacuum Oil Company, 60 miles, 8-inch, gas, main, in South Sumatra, considered.

Ste. d-Etudes de Pipeline Intercontinetaux, Paris, 1,400 miles, 30-40-inch, gas, from Hassi R'Mel field in central Algeria across Mediterranean, through Spain, France and into West Germany, considered, Fish International Corporation making engineering and feasibility studies.

Sui Gas Transmission Co., Multan, Punjab, India, 145 miles, 8-inch, gas, from Sylhet to Dacca, East Pakistan, $9 million, considered.

130 miles, 16-inch, gas, main line, Multan to Lyallpur, planned.

Continued on Page 74

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NOW
specific
GRAVITY RECORDING
OF LIQUIDS AT ANY
DISTANCE
MODEL RMT
Accurate long-distance transmission of specific gravity recordings is no longer a problem with any of the new RMT Models of Arcco-Anubis Recording Gravitometers for recording and transmitting liquid gravity records. These instruments combine the mechanism of the standard Arcco Liquid Gravitometer with a metameter telemeter transmission system which records and transmits the specific gravity record to control room or other remote location. The inter-connecting line may be any two-wire electrical circuit or its equivalent: private wires, telephone circuits, carrier current channels, or radio (VHF or UHF).
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PLANT IN HOUSTON INCREASES OUTPUT OF

THE BETTER TAPE COATING

Plicoflex, the line proved protective tape coating, combines butyl rubber and polyvinyl chloride to give these important advantages:

1. *Shock Impact Resistance*
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4. *Economical Installation*
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The outer layer which is of vinyl now contains flame resistant chemicals. It provides strength, toughness, abrasion resistance, and permanence. With the butyl side applied against the primed surface, crevices and scratches are filled, leaving no gaps between tape and pipe.

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Efficient new Houston plant facilities give you improved quality tape at reduced prices.

PROPOSED CONSTRUCTION

continued

Syrian Pipeline, Damascus, 500 miles, crude, from Karshuk field, Syria to Mediterranean, planned.

300 miles, products, from Homs to tank farms in Damascus, Aleppo, and Latakia, planned.

Trans-Canada Pipe Lines Limited, Toronto, 50-mile, 30-inch, gas, lateral, Winnipeg to Emerson, Manitoba; 74 miles, 34-inch, loops, additional compressor hp at Swift Current, and Indian Head, Saskatchewan, and Portage la Prairie, Manitoba, $45 million, planned.

268 miles, 34-inch, loops, and additional hp planned for 1961, $69 million.

122 miles, 34-inch, loops, hp additions, $46 million, planned for 1962.

Trans-Prairie Pipelines, Ltd., Edmonton, crude line, from Weyburn field to Regina-Moose Jaw areas, $5 million, considered.

Westalta Products Pipeline Ltd., 900 miles, LPG, from Northern Alberta to Saskatchewan border, to deliver hydrocarbons to Foothills Pipe Lines, $40 million, before Alberta Board of Public Utilities Commissioners.

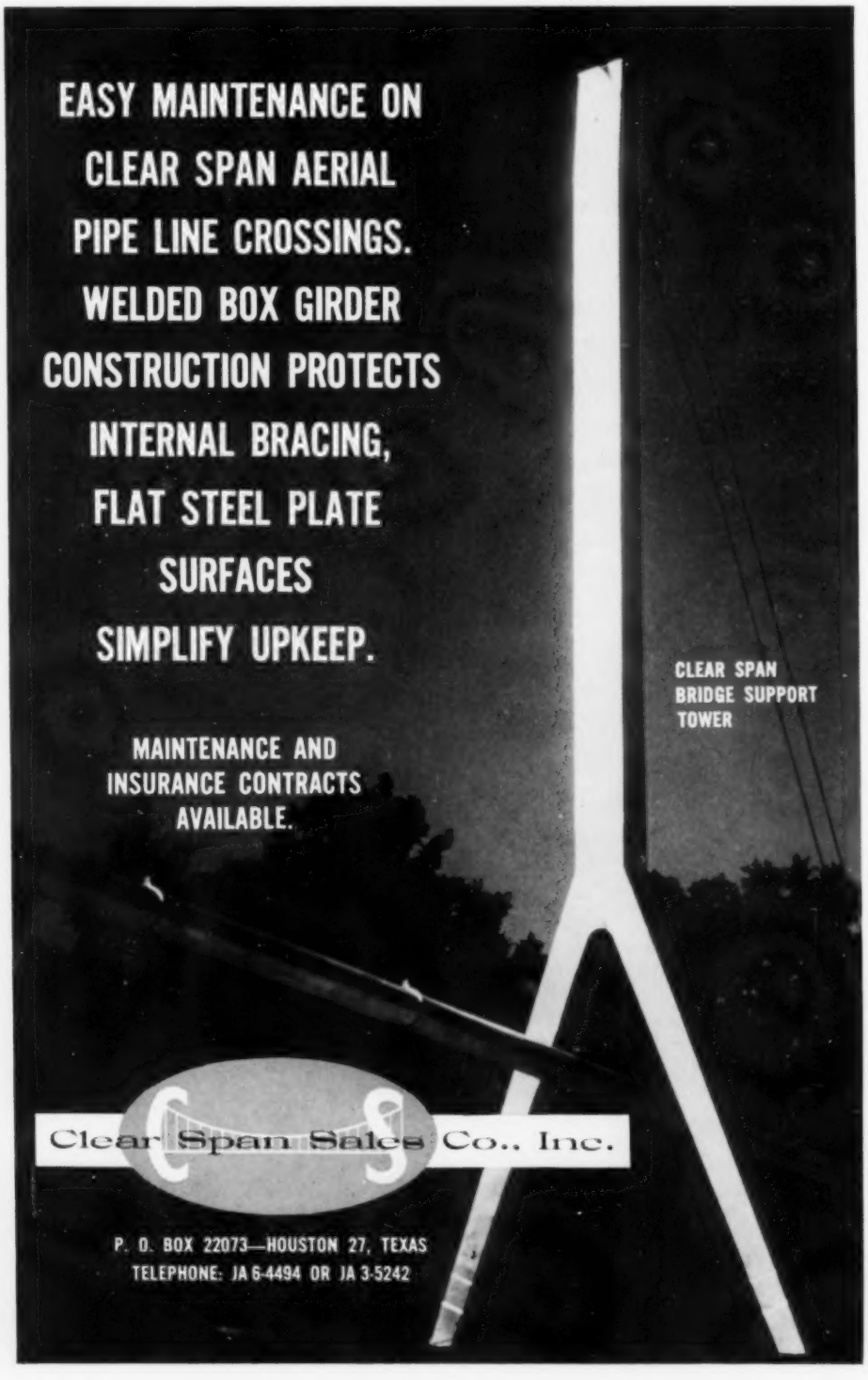
Westcoast Transmission Company, Ltd., 250 miles, 30-inch, gas, Taylor to Fort Nelson, B. C., planned.

Williams-McWilliams Industries, Inc., New York, 441 miles, 6-inch, crude, Villa Montes, Bolivia to Villa Hayes, Paraguay, considered.

Yacimientos Petroliferos Fiscales, Buenos Aires, Argentina, 621 miles, 12-inch products, Mendoza to San Lorenzo, Argentina, $19 million, planned.

450 miles, 16-inch, crude, from Neuquen Province to Bahia Blanca, planned

Yacimientos Petroliferos Fiscales Bolivianos, La Paz, 407 miles, 12-inch, crude, Camiri to Sica Sica, planned.



Construction to Begin Soon On Mid-America Pipe Line

Williams Brothers Company will begin work this month on the first phase of Mid-America Pipe Line Company's 2,000-mile LPG line to Minnesota and Wisconsin.

Construction plans call for the first section from Texas-New Mexico Panhandle area to McPherson, Kan., to be completed by October. Williams Brothers will have two spreads working on 673 miles of the 8 and 10-inch pipe line.

Capacity of the LPG line will be 50,000 barrels daily to McPherson; from McPherson separate lines will be laid to St. Paul, Minn., area and Milwaukee area with initial capacity of 30,000 barrels daily for each line.

Humble Pipe Line Co. Plans 63-Mile Crude Line

Humble Pipe Line Company will construct a 63-mile, 8-inch crude line and gathering system in Southwest Texas. The line will extend from Sacatosa field in Maverick County to the company's system at Pearsall. The line is expected to be completed in early summer.

New Haven Pipeline Plans New England Products Line

A proposal for a products pipe line from New Haven, Conn., to Springfield, Mass., has been made by New Haven Pipeline, Inc., a new company. Plans call for the line to be laid along the New Haven Railroad right-of-way; it will have a capacity of 60,000 barrels per day. Cost would be about $2½ million and the carrier will transport aviation fuels, gasoline, kerosine and fuel oil.

Cape Construction Awarded Contract by Illinois Power

Illinois Power Company has let contract to Cape Construction Company to lay 22 miles of 12, 14, and 16-inch pipe line near Belleville, Ill.

TRANSWESTERN
Transwestern's pipeline to carry Texas and Oklahoma gas to the West Coast, largest gas transmission project for 1960, is now scheduled for completion in July. Thus, the more than 1800-mile system will have been laid through some of the roughest terrain under unusually severe weather conditions well ahead of the original target date. Houston Contracting, a prime contractor on the project, is proud to have contributed to this record.
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ON THE LINE

The Alfred L. Kleberg Engineering Building where the fifteenth annual gas technology short course will be held at Texas A&I, Kingsville, Texas. Dates are June 1-3.

Gas Technology Short Course

The fifteenth annual short course in gas technology will be held at Texas College of Arts and Industries, Kingsville, Texas, June 1-3.

Ten papers will be presented in the transmission section covering such subjects as gas turbine applications, liquid methane storage, pipe testing, controlling gas hydrates, dehydration of natural gas, polyethlene pipe for low pressure gathering systems, determination of pipe line efficiencies and automation.

M. V. Cousins, chairman, short course advisory committee, will preside at the opening session. Welcoming address will be delivered by Dr. E. H. Poteet, president, Texas A & I College, and response will be given by James A. Wilson, president, Southern Gas Association. Principal address will come from Edward H. Smoker, president of The United Gas Improvement Company.

For information on enrollment write Dr. Frank Dotterweich, Texas A & I, Kingsville, Texas.

Tennessee Gas Building Offices

Tennessee Gas Transmission Company will construct a 25-story office building in Houston. The building will occupy two-thirds to three-fourths of a block at Milam, Louisiana, Lamar and McKinney.

A subsidiary, Tennessee Gas Building Corporation, is being organized to own and operate the office building. C. A. Lingo, senior vice president of Tennessee Gas, will serve as president. The building will be exclusive for Tennessee Gas, its operating divisions and subsidiaries.

The 22-story Tennessee Building will be retained by the Tennessee Life Insurance Company.

AGA President Speaks

In an address given at the annual New England Gas Association meeting, Wister H. Liston, AGA president, said that the nation's proved recoverable natural gas reserves reached an all-time high of 262.6 trillion cubic feet at the end of 1959. This was despite the record production of 12.5 trillion cubic feet during the year.

Liston added that according to reports, ultimate reserves amount to between 1,100 and 1,700 trillion cubic feet, with the average estimate about 1,400 trillion cubic feet. At current levels of production, this average figure represents at least 100 years supply. These estimates do not include the huge supplies of gas known to exist in Mexico and Canada.

Arnold O. Beckman Award

The Arnold O. Beckman award has been established by the Instrument Society of America in honor of Dr. Arnold O. Beckman, former president of the society and an honorary member.

The annual award will be given to an ISA member making the most important technological contribution to the conception and implementation of a new principle of instrument design, development or application. It will consist of a citation and a cash prize of $1,000.

Its objectives, according to the ISA, are:

To stimulate the conception, design, and development of new principles of instrument design, development and application

To acknowledge and reward individuals who make such contributions

And to honor the contributions and exemplary achievements of Dr. Beckman.

The contribution of each nominee for the first award, to be made at the society's annual meeting in New York in September, must have been described substantially by at least one published paper, patent or unclassified formal report bearing a date falling within the two-year period ending October 31, 1959.

Nominations for the first award are being received by William H. Kushnick, Executive Director of ISA, 313 Sixth Ave., Pittsburgh, Pa. They will close soon to permit judging for the award.

France Is Busy

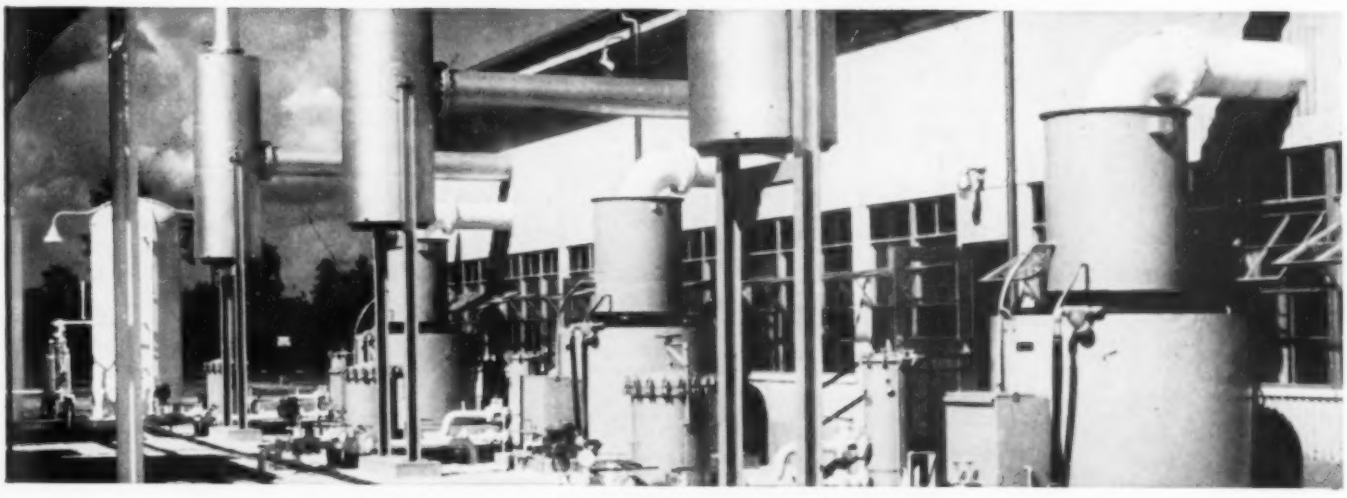
France's growing industry has put 43 percent of its total population to work, compared to 40 percent of America's population, according to *France Actuelle*, bi-weekly publication on French business activities.

Highest in the list mentioned is West Germany with 50 percent. United Kingdom has 46 percent at work, Italy 41, Belgium 39 and Canada and the Netherlands are even at 37 percent.

The 57 percent "at play" in France are either too young, too old, too sick, at school, in military service, or just not working and not classified.

A word to the wives and wise. Among those at work, women live longer and work longer, according to the article in *France Actuelle*.

AAF cleans gas...



...as well as air on new Texas-Florida pipeline

● On Houston Corporation's new Texas-to-Florida pipeline, both intake air for compressor engines AND gas being pumped are cleaned by AAF!

The pipeline – operated by Houston Texas Gas and Oil Corporation – is bringing natural gas to Florida for the first time. And it's *clean* gas, too, after it passes through AAF horizontal gas cleaners (top photo). These oil-bath cleaners (installed at all compressor stations on the line) remove liquids, contaminants, and foreign matter from the gas before it goes into the compressors for transmission.

Smoother engine performance is assured by AAF Cycoil Kool-Airs (bottom photo). These combination cleaner-coolers – which also operate on the oil-bath principle – condition intake air before it goes into the engine.

American Air Filter can help with *your* air- or gas-cleaning problem – wherever it might be in the petroleum or petro-chemical industry. You can get complete information from your nearest AAF representative, or by writing Mr. Robert Moore, American Air Filter Company, Inc., 450 Central Avenue, Louisville, Kentucky.

AAF **American Air Filter**

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For more data on advertised products, use Readers' Service Cards, last page.

PRACTICE MAKES PERFECT!

Tried and Proven Automated Systems for Crude, Natural Gas, and Products Pipe Lines

Maloney spheres — from 1½" to 36" — now are at work in pipe lines of all sizes and purposes. Semi- and fully-automated pipe lines are using Maloney spheres* and automation techniques* to increase efficiency and reduce operating costs.

Maloney engineers and production facilities are available for consultation, design, and manufacture — in solving your squeegee operation problems.

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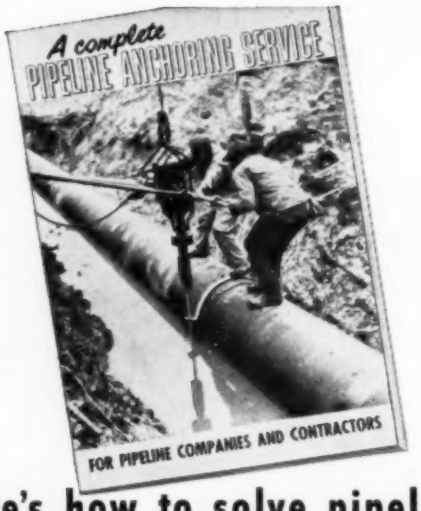

Here's how to solve pipeline floatation problems...

Use the Chance Field Service Plan . . . the surest, easiest, most reliable, and least expensive way to anchor pipelines. You'll cut costs about 85% by using Chance Screw Anchors and tie-down brackets. And, you can have the whole project engineered, installed, and tested by qualified technicians at far less cost than counter weighting.

By making soil test probes, Chance engineers can tell you where anchors should be used, the sizes needed, and the proper depth. To learn how you can get the whole anchoring job done quickly, easily, inexpensively—send or call for this booklet.

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What's Happening

among MEN in the INDUSTRY

Posthumous Citation Awarded Texaco Engineer

A posthumous citation of appreciation is presented to Mrs. Rolland W. Phillips for her late husband by the Department of the Army. The award is in recognition of Phillips' distinguished service in voluntarily assisting in the operation and maintenance of military petroleum pipe lines. He had served as a consultant to the Alaska Petroleum Distribution System and as an advisor and instructor of Army-sponsored French pipe line personnel. At the time of his death last year, he was assistant general manager of the Texas Pipe Line Company. Major General A. T. McNamara, Quartermaster General, left, made the presentation to Mrs. Phillips and her son Thomas R. Phillips.

Pacific Gas and Electric Company has appointed **Ralph S. Nabors** general superintendent of pipe line operations. He succeeds **E. Howard Fisher** who was recently named vice president in charge of gas operations.

Harry P. Prudhomme, formerly superintendent of the northern division of pipe line operations, replaces Nabors as superintendent of transmission and compression. Succeeding Prudhomme, **Robert W. Brooks** was named superintendent of the northern district.

William C. Thrailkill has been named superintendent of **Transcontinental Gas Pipe Line Corporation's** Gas Control department. He joined Transco in 1950 as a senior dispatcher. Thrailkill succeeds **C. M. Springer** who is on an 18-month leave of absence in Argentine with Fish Engineering Corporation. He will organize a gas dispatching and control staff composed primarily of Argentine citizens.

William B. Padon has been named vice president of administrative affairs for **Transwestern Pipeline Company.** He had been a vice president and director of Warren Petroleum Corporation.

Padon has been associated with Warren since 1939. He became vice president in charge of projects and planning in 1956. Transwestern is owned by Warren, Monterrey Oil Co., and J. R. Butler and Associates of Houston.

Gordon W. Walker has been elected president of the Pipe Line Contractors Association of Canada. Walker is manager, **Pipeline Division of Mannix Co. Ltd.**

Gordon W. Walker

Other officers selected at the annual convention held in Victoria, B.C., February 25-27, are **W. Douglas Porter,** vice president and general manager of **Mid-Canada Contractors Ltd.,** first vice president; **W. A. Rose,** president of **Majestic Contractors Ltd.,** second vice president, and **George A. Wilkinson,** vice president of **Marwell Construction Ltd.,** treasurer.

Directors for the year include **W. I. Daniels,** assistant to president, **Dutton-Williams Bros. Ltd.; Ron K. Banister,** president, **Fulton Banister Ltd.; R. B. Somerville,** president, **Robert B. Somerville Co., Ltd.,** and **D'Arcy J. Baldwin,** president of **Marine Pipeline and Dredging Ltd.**

Oakite cleaning methods pay off fast. At pumping stations they help step up product flow, save time, reduce maintenance costs. Take these typical operations, for instance:

Diesel parts cleaning. A short soak in Oakite Saturol removes every trace of carbon, varnish, lacquer, gum, grease ... yet hand brushing is eliminated.

Lube oil cooler maintenance. Oakite Compound 85 does double duty — removes both grease and scale in a single operation. Units go back on stream faster, and at full rated capacity.

Cleaning electrical equipment. For maintenance of generators, control panels and electric motors, Oakite Composition 117 is the specific-purpose solvent with the two essential qualities you want: high flash-point and quick loosening of soil.

These and similar operations at pipeline pumping stations are discussed in a new Oakite Service Report, B6878. For a free copy of this helpful report, write to Oakite Products, Inc., 51A Rector Street, New York 6, N.Y.

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over 50 Est. 1909 years' leadership in industrial cleaning

SCIENCE

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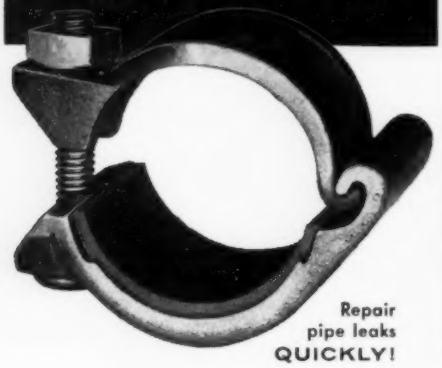
Technical Service Representatives in Principal Cities of U. S. and Canada

For more data on advertised products, use Readers' Service Cards, last page.

For Speediest Repair of Corrosion Leaks in Pipe

JUNIOR

EMERGENCY PIPE CLAMP



Repair pipe leaks QUICKLY!

Speediest application — slotted lug permits the single plated bolt to slide instantly into place.

A companion to the old reliable Emergency Pipe Clamp that has served industry for a half century, the JUNIOR, a single bolt clamp, is 2⅞" wide. Undersells most band-type clamps.

Made of malleable iron, ruggedly proportioned, with full-length hinge along one side. Formed to exact pipe size—no bending. The recessed pressure-equalizing gasket, entire width of clamp, is cemented in. A lasting installation. 2" pipe size—$1.80; 2½"—$2.20; 3"—$2.30. Write for new circular on the Junior.

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EMERGENCY PIPE CLAMPS for safe, sure lasting repair of splits and rust holes in pipe. No pressure too high. Anyone can apply in a few moments. Made in all sizes, ½" to 12", for steel and C. I. pipe. Stocked by practically all oil supply stores.

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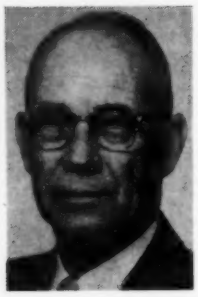
W. S. Spangler



A. E. Pecore

W. A. Castille

P. D. Phillips, Jr.

Election of **W. S. Spangler** as president of the company was announced by **Humble Pipe Line Company. W. A. Castille** and **P. D. Phillips, Jr.**, were named vice presidents in other administrative appointments.

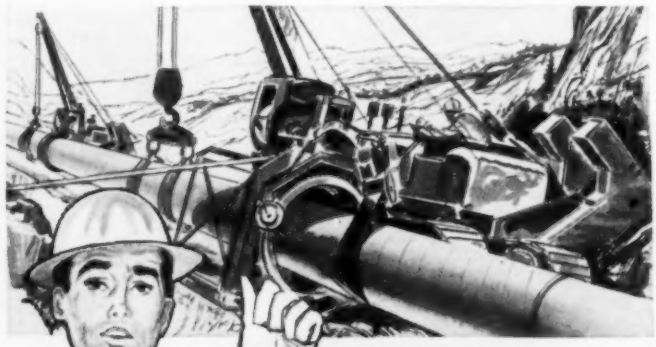
Spangler succeeds **A. E. Pecore** who retired after 40 years service with Humble. Pecore joined the company in 1919 as a draftsman. He was made chief engineer in 1944, promoted to general superintendent in 1949, became vice president in 1950, and was elevated to president in 1957. Spangler joined Humble in 1933, and in 1944, was named office engineer. He was promoted to assistant division superintendent in 1945, general superintendent in 1951, and was elected vice president in 1957.

Castille, acting assistant general manager, is now vice president—operations. In 1959, he joined the pipe line company after serving with Humble Oil & Refining Company as assistant chief engineer. Phillips becomes vice president—planning and economics. After joining the company in 1934 he served in various capacities until 1942, when he entered armed forces. He returned to Humble in 1946, was named chief engineer in 1951, and in 1956, became assistant general superintendent. He was named general superintendent in 1957, and assistant general manager in 1958.

Stephen H. Baer, director of public relations for **Pacific Lighting Gas Supply Company,** has been named to head personnel functions of the company. He becomes public relations and employe relations director. He has been with the company since 1958. Previously, he had been on the news-publications staff of Southern Counties Gas Co. and for three years was head of the staff.

He held publicity posts with the Los Angeles Chamber of Commerce and Los Angeles Junior Chamber of Commerce prior to joining Southern Counties in 1954.

Russell T. Tutt has been elected a member of the board of directors of **Colorado Interstate Gas Company.** He succeeds the late **F. T. Parks. Tutt** has been a vice president and trustee of the El Pomar



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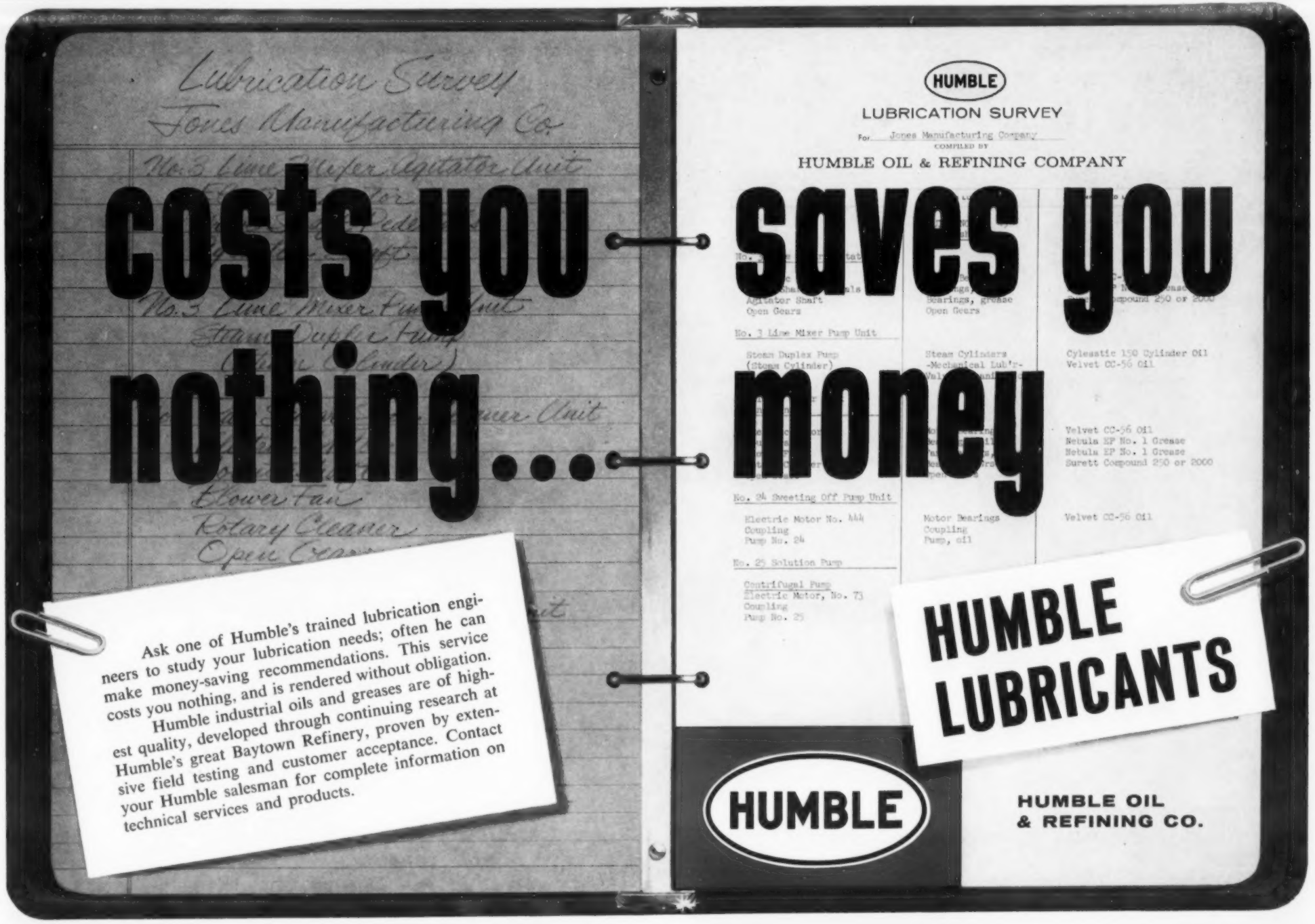
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Garlock Inc. becomes the new name for The Garlock Packing Company, Palmyra, N. Y., to reflect more accurately its broad diversification of products and markets.

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- Plastic Stock Shapes and Fabricated Parts
- Mechanical Seals for Rotating Shafts
- Metal Packings
- Leather Packings
- Electronic Components
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- Fluorocarbon Tank Linings
- Missile and Rocket Components

To help you in selecting or applying these products, Garlock offers the services of over 126 thoroughly-trained sales engineers, 175 electronic component manufacturers' representatives, 180 authorized bearing distributors and 69 foreign distributors. Conveniently located warehouses and stocking points assure Garlock customers of prompt delivery.

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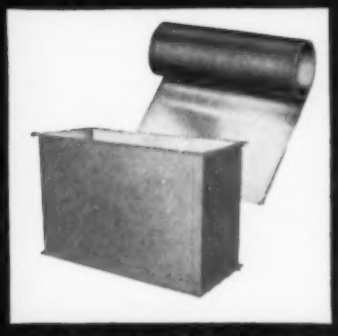
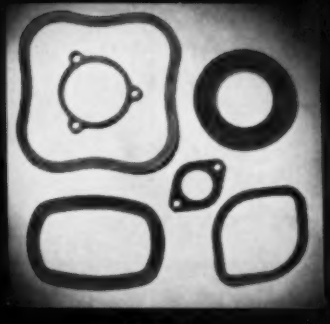


Fluorocarbon Tank Linings

Oil and Grease Seals

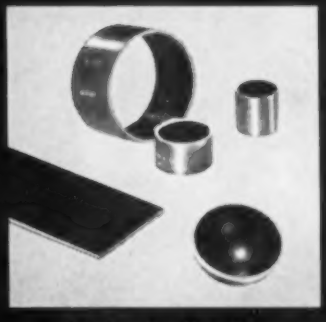
Mechanical Shaft Seals



Gasketing

Spiral Wound Gaskets

Metal Packings



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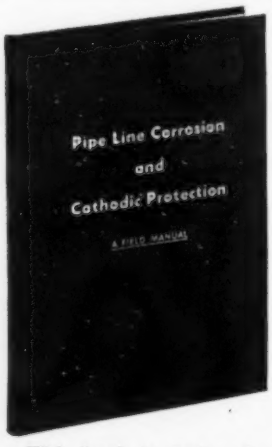

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He was vice president and general manager of the Garden City Company, and president of the Southwest Kansas Power, Inc., from 1946 to 1956.

C. T. Carter

Malcolm J. Frazier

Malcolm J. Frazier and **C. T. Carter** have been elected to the board of directors of **Sinclair Pipe Line Company.** Frazier also was elected secretary-treasurer, succeeding the late **John P. Main** who died January 31. Joining Sinclair in 1933, Frazier formerly had been treasurer of Sinclair Rubber, Inc., and recently held the post of treasurer of Sinclair Research Laboratories, Inc. He will be headquartered in Independence, Mo.

Carter, director of engineering, replaces **A. M. Stafford** who retired. He joined Sinclair in 1938, and has had various assignments before being named to his present position.

E. D. Brockett was elected executive vice president and a director of **Gulf Oil Corporation.** Other executive promotions include **David T. Seals** and **Kermit Roosevelt** appointments as vice presidents.

Brockett, who has been with the company since 1934, became vice president in charge of Houston Production Division in 1955. In 1958 he was elected a director, president and chief executive officer of the British American Oil Company Limited. He became executive vice president of Gulf when he rejoined the company at the beginning of the year. Searls, general counsel for Gulf, joined the company in 1958. He will continue to be responsible for all corporate legal matters. Roosevelt joined Gulf as director of government relations in 1958. He has been a consultant to the secretary of State on matters concerning the Middle East. He will continue to maintain liaison, from Washington office, between the company and government agencies of the U.S. and foreign countries where Gulf operates.

Appointment of **Felix B. Probandt** as secretary and treasurer has been announced by **Pipe Line Technologists, Inc.** Probandt had been with the Tax Department of Peat, Marwick, Mitchell & Co.

New York State Natural Gas Corporation has named **Clifford P. Cleland** superintendent, lease-northern area, with headquarters in Sabinsville, Pa., northern division offices. He replaces **James M. Hawk** who has retired.

Cleland joined the company in 1952, and served as leaseman until his recent promotion. He formerly was with Steuben County, N.Y., clerk's office as title searcher.

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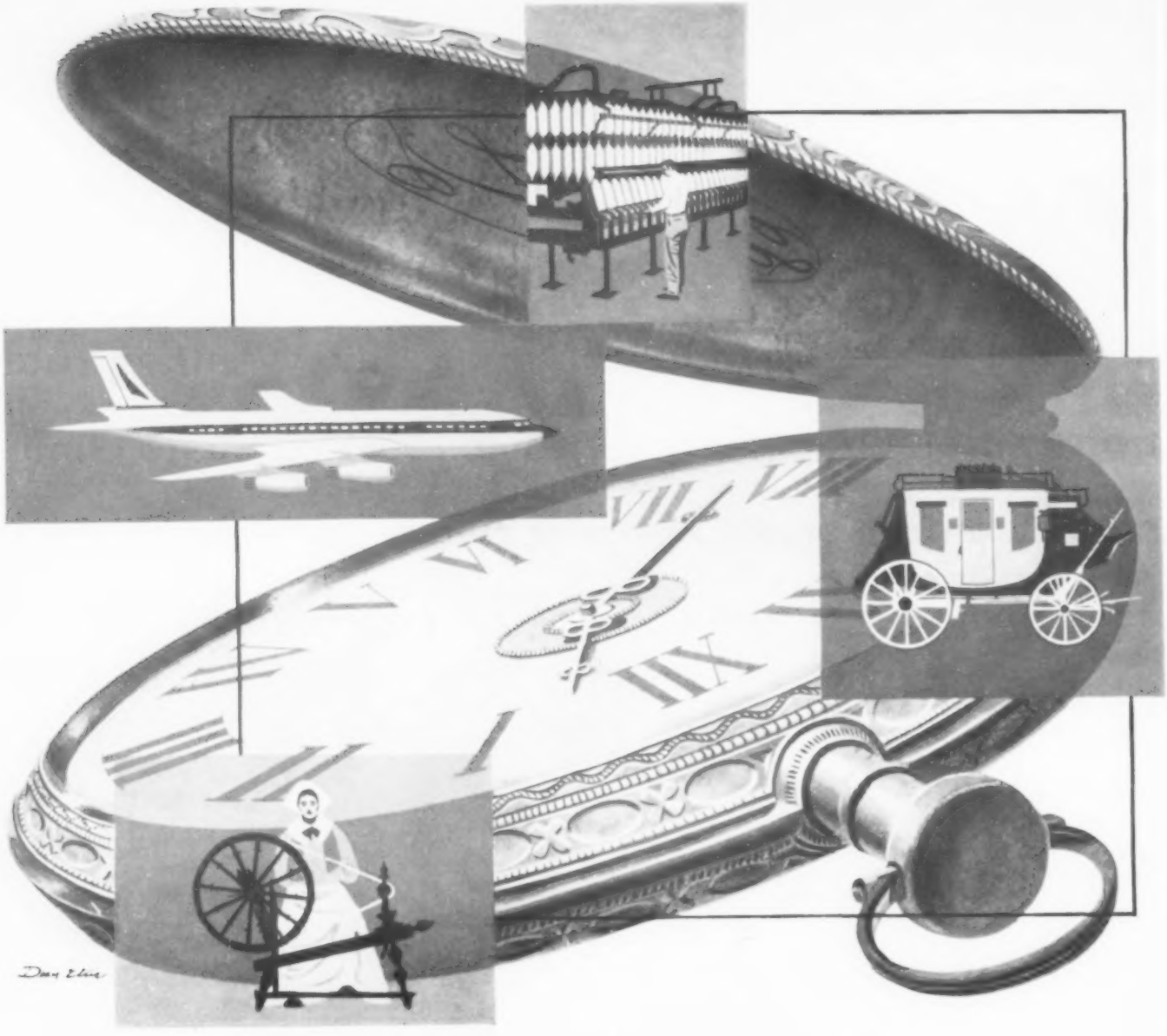

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J. R. Wright

K. W. Miller

L. A. Foy

M. E. Powell

Completing a major realignment of field operations, **Magnolia Pipe Line Company** has named four division managers and reduced its field operations from five divisions and 19 district offices to four divisions and nine district offices. Eight supervisory areas will report to the district offices.

Division managers and headquarters include **M. E. Powell**, Houston; **K. W. Miller**, Midland, Texas; **J. R. Wright**, Wichita, Kan., and **L. A. Foy**, at Plainfield, N.J.

District headquarters for Houston will be Alice, Beaumont and Corsicana, Texas. Area supervisors will be at Corpus Christi and Greggton, Texas. Midland District headquarters are at Wichita Falls, Midland and Brownfield, Texas. Andrews, Texas, and Healdton, Okla., will be area supervisor headquarters. In the Wichita Division district headquarters will be in Augusta and Hill City, Kan., and Salem, Ill., with a supervisor at Casper, Wyo. The Plainfield Division will have area headquarters at Harrisburg, Pa., Rochester, N.Y., and East Douglas, Mass.

Panhandle Eastern Pipe Line Company announces promotion of seven persons in compressor station positions. **K. E. Kalen** becomes assistant to vice president, gathering and transmission; **G. J. Gillian** is now superintendent of compressor stations, and **C. J. Witt** is assistant superintendent of compressor stations. **Charles B. Amick** was named maintenance engineer in Kansas City office; **Ralph E. Hilbig** becomes Region 4 superintendent at Crawfordsville, Ind.; **James H. Budden, Jr.**, is plant superintendent at Tuscola and **Lee S. LaDow** was made plant superintendent at Glenarm.

Kalen had been superintendent of compressor stations for the past four years. He has been with the company since 1949. Gillian, who had been with Panhandle for 23 years, had been assistant superintendent for four years. Witt joined the company in 1935 and came to Kansas City in 1957 as maintenance engineer. Amick had been regional superintendent at Crawfordsville before his promotion.

Southern California Gas Co. announces the election of **Harry P. Letton, Jr.**, as vice president and general counsel. He succeeds **T. J. Reynolds** who has served as vice president since 1927.

Letton, who was elected to the board of directors in 1958, has been general attorney for the company since 1957. He joined the firm in 1951 as assistant general counsel.

R. Melvin Hunter has been named director of public relations and industrial development for **Northern Ontario Natural Gas Company Limited** and **Twin City Gas Company Limited.** Hunter had been general manager of Twin City Gas Company Limited. Previously, he was with the Saskatchewan Power Corporation, and also had served with the Manitoba Power Commission.

F. Irving Yewman was appointed general manager of the **Twin City Gas Company Limited,** and will be in charge of sales, advertising, dealer relations and public relations. He had been manager of Lakeland Natural Gas Company Limited, in Kingston, Ont., before joining Twin City.

Warren Petoleum International Corporation announces the appointments of **E. D. Brockett** and **I. G. Davis** to the board of directors. Brockett is executive vice president of **Gulf Oil Corporation,** a member of the board and the executive committee. Davis is a senior vice president of Gulf.

A subsidiary of Gulf Oil Corporation, Warren Petroleum International was organized to market liquefied petroleum gas.

Deaths

Harry Cain, 60, assistant public relations director of **United Gas Corporation,** died March 26 at home in Shreveport, La. He had been with the company since 1936. He was named manager of the Lufkin, Texas, office in 1942, and district manager in Longview, Texas, in 1944. He was assistant division manager for the company in Beaumont, Texas, in 1949. In 1950 he moved into the Public Relations Department in Shreveport.

He was a member of the American Gas Association, Southern Gas Association, Louisiana-Arkansas Division of Mid-Continent Oil and Gas Association, and a member of the Natural Gas Industry Television Committee of AGA.

J. D. Davis, 59, a vice president of **United Gas Corporation** and a 35-year veteran with the company, died March 30. He had served in various capacities with the United Gas Pipe Line Company and its parent firm. He was a director of the pipe line company, assistant to the president of United Gas Corporation and in 1959, was named a vice president.

Davis, as vice president, was responsible for coordination of the Texas and Louisiana-Mississippi distribution divisions and handled all general office matters relating to the distribution operations of United Gas. He was a member of the United States Chamber of Commerce, American Gas Association, American Petroleum Institute, Independent Natural Gas Association of America, Southern Gas Association and Texas Mid-Continent Oil and Gas Association.

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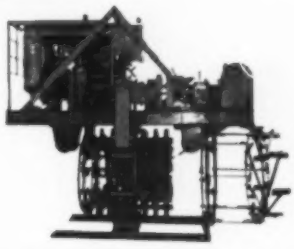

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What's Happening among SERVICE and SUPPLY MEN

Grove Valve & Regulator Co. Names Carter District Manager

Charles Carter has been named district manager in the New York region for Grove Valve & Regulator Company. He will direct sales of Grove valves and regulators in the Middle Atlantic and New England states.

Carter has been with the company for five years; previously he had been in the Houston office.

Robert J. Lingle (left) and San Jacinto Gaido of the Gaido-Lingle Co., Inc., have recently completed an expansion program of their pipe coating and wrapping plant in Houston. The company also has opened a Dallas office and appointed a South Texas-Louisiana representative.

Pipe is unloaded from truck onto pipe racks, left, at Gaido-Lingle's newly expanded plant. The company is equipped to handle internal and external coatings on all sizes of pipe. Gaido-Lingle now has 27,000 feet of working space under cover.

Gaido-Lingle Co., Inc. Expands Coating Facilities

Within two years after its establishment, Gaido-Lingle Co., Inc., has completed its first major plant and office expansion.

The pipe coating and wrapping company, founded in April 1958, now has two complete plants under cover, recently opened a Dallas branch office and is set up to handle internal and external coatings on all sizes of pipe.

By expanding its operating facilities, Gaido-Lingle has 27,000 square feet of working space under cover. The plants are equipped to handle all external coatings including coal tar, asphalt, tapes and coal tar epoxies. The Houston firm also has entered internal coating field and recently internally coated approximately 170,000 feet of 4-inch pipe for a Venezuelan pipe line.

Located at 739 Aleen Street in Houston, the yard is accessible to barge terminals, public docks, truck lines and rail transportation.

Responsible for the establishment and development of the service company are San Jacinto Gaido and Robert J. Lingle. Gaido, who spent 11 years with Pipe Line Service Corporation, is a graduate of the University of Houston where he studied mechanical engineering. At Pipe Line Service, Gaido was plant manager of the Harvey, La., yard. He is a member of the NACE, Pipe Liners Club and Southern Gas Association.

Lingle, who studies petroleum engineering at Texas A&M, has had 15 years experience in the pipe coating and wrapping industry. In addition to the NACE, Pipe Liners Club and Southern Gas Association, Lingle is an active member in the Aircraft Owners and Pilots Association.

Union Switch & Signal Names Four Area Representatives

Four sales engineers have been appointed area representatives by Union Switch & Signal Division of Westinghouse Air Brake Company. They will be concerned with pipe line control systems and equipment in the United States and Canada.

Eastern area representative is Gerald M. DuBois; Robert J. Cook will handle Midwestern area; William F. Haley, Southwestern area, and James H. Stelloh becomes Western area representative.

Allis-Chalmers Announces Four Managerial Appointments

Charles F. O'Riordan becomes manager, North Central region; Robert E. Morris, manager of Midwest region; J. A. Sudduth, manager St. Louis district; and William S. Wright, manager Grand Rapids district for Allis-Chalmers Manufacturing Company Industries Group.

O'Riordan succeeds M. M. York who has been assigned to a Milwaukee position. Manager of the company's Midwest region since 1956, O'Riordan will be responsible for district offices in Chicago, Peoria, Rockford, Milwaukee, Des Moines, Davenport, Minneapolis, Duluth and Appleton. Included in Morris' region are district offices in St. Louis, Kansas City, Evansville, Indianapolis, Louisville, Memphis, Omaha and Wichita. Sudduth previously had been manager of Grand Rapids district and Wright was sales representative in Grand Rapids district.

Bud Glenn Named Manager Of Operations for Crose-Curran

Bud Glenn, formerly branch manager of the Toronto division, has been appointed manager of operations for Crose-Curran, Ltd., with headquarters at the company's main office in Edmonton, Alberta.

Harvey Gordon will be Glenn's assistant in the Sales Department in Edmonton area. Bob McLean becomes office manager and Bill Clark is in charge of the Shop and Service departments. In other appointments, Roger Garneau becomes office manager of the Toronto division and Frank Munshaw, formerly of Cessco, is in charge of sales and services in Toronto.

Jones & Laughlin Announces Several Field Sales Changes

Several changes have been made by Jones & Laughlin Supply Division in its field sales force. F. B. Barnett is now city sales manager at Ft. Worth; O. A. Bergmann was named regional salesman tubular products, central division; H. L. Kymen is regional salesman, tubular products for Gulf Coast region; and R. Z. Dallas was made salesman at Amarillo.

Other appointments include J. W. Snyder being made salesman at Luling, Texas; W. M. Wilkinson, Jr., becomes salesman at Alice, Texas; S. D. Bull was named salesman at Laurel, Miss.; J. N. Ryan is now salesman at Clarksburg, W. V.; W. E. Hamon, Jr., was assigned to Dallas city sales office, and C. V. Hester was promoted to salesman at Midland, Texas. F. E. Vanderbilt becomes salesman at McComb, Miss.

Hugh A. Saye, Joins SIE As Assistant Marketing Manager

Hugh S. Saye, Jr., has been named assistant marketing manager of Southwestern Industrial Electronics Controls Division. Saye comes to SIE from Fisher

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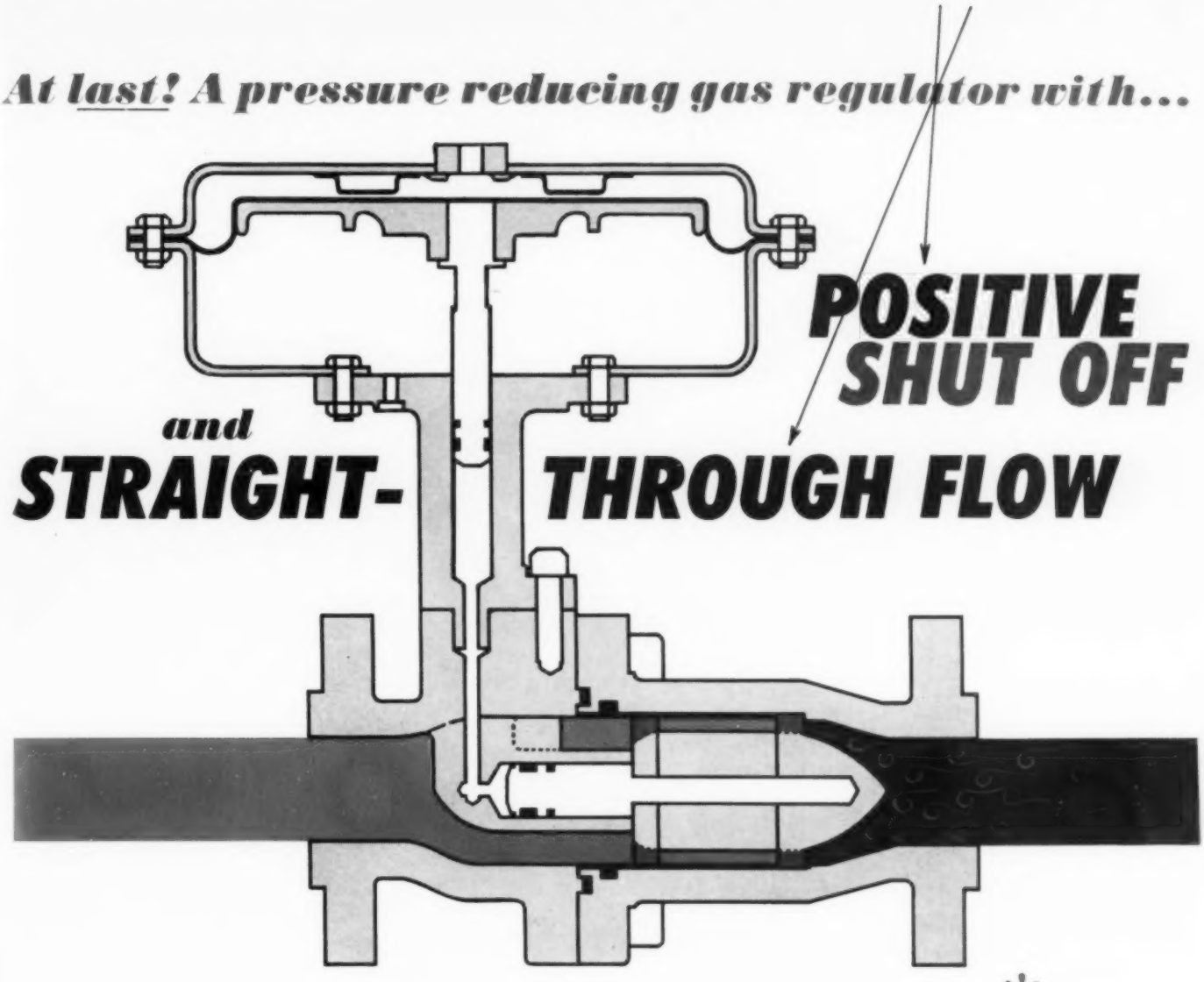

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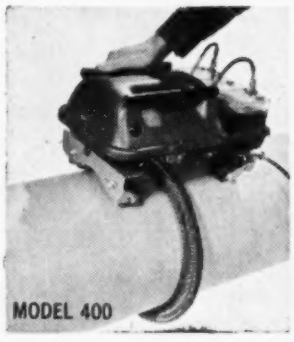

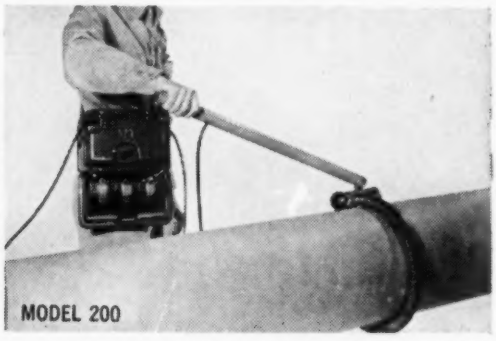

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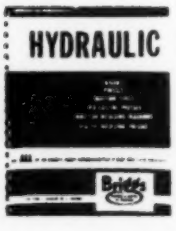

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ADDRESS_____

Governor Co. He will direct sales engineers in pipe line, oil lease and process industry automation. He has been in the automation field 11 years.

M. H. Jackson Organizes Pipe Line Supply Company

M. H. Jackson has established the M. H. Jackson Pipeline Supply Company with offices in Tulsa. The company will be a distributor for several products in the pipe line business. Included in the array of products are coating and wrapping materials, beveling machines and small diameter pipe.

United States Rubber Co. Promotes John V. Glaves

John V. Glaves has been promoted to Houston district sales manager by United States Rubber Company. He replaces J. Wesley Batten who retired after nearly 33 years service with the company. Glaves has been with U. S. Rubber since 1948 and was headquartered 10 years in Tulsa. Before his recent appointment he was assistant district sales manager in Houston.

Toliver Named Sales Manager for Tube Turns

Jack D. Toliver becomes field sales manager for Tube Turns Division of Chemetron Corporation. He had been eastern regional sales manager and now will have supervision of sales in all United States district office territories. He joined the company in 1949, was made manager of sales development in 1955, Eastern regional manager in 1958.

Cal-Metal Pipe Corporation Names New Vice President-Sales

Ken Bayless, assistant sales manager, has been appointed vice president-sales for Cal-Metal Pipe Corporation. Before joining Cal-Metal, he was general sales manager of a Jacksonville, Fla., steel and aluminum pipe manufacturer.

Sam B. Raia, Jr.

C. F. Wilson

Gaido-Lingle Appoints District Sales Managers

Sam B. Raia, Jr., has been named sales engineer for South Texas and Louisiana, and Charles F. Wilson becomes Dallas-Ft. Worth representative for Gaido-Lingle Co., Inc.

Raia formerly was associated with Fish Service Corporation and Valley Gas Transmission Company. He served in pipe line engineering, inspection and surveying for southern division for the gas company. Wilson had been with Lone Star Gas Company for 36 years in the Purchasing Department. Prior to retiring from Lone Star he was president of the Dallas Purchasing Agents Association in 1947. He will headquarter in Gaido-Lingle's newly established Dallas office at 1025 Life Building.

LATEX OFFERS EXPERIENCE FOR YOUR CONSTRUCTION NEEDS...

LATEX has been associated with the oil and gas industry for over a quarter of a century. Enjoying repeat business from people and companies who demand quality construction. Pipelines are *LATEX'S* Business.

Another quality service of *LATEX* is
CONSTRUCTION OF DISTRIBUTION SYSTEMS.
Invite *LATEX* on your next program.

REMEMBER, LATEX QUALITY CONSTRUCTION BRINGS REPEAT BUSINESS AGAIN AND AGAIN

LATEX
SERVING 1/4 CENTURY

LATEX CONSTRUCTION COMPANY

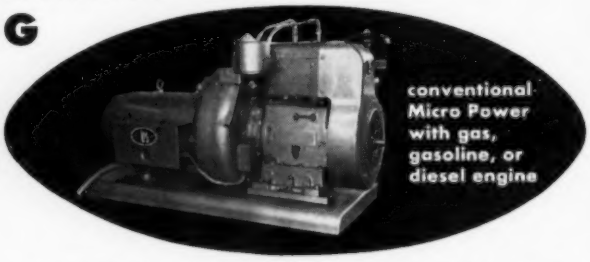
P. O. BOX 12128 • ATLANTA 5, GEORGIA • CE 3-9414

For more data on advertised products, use Readers' Service Cards, last page.

EL PASO NATURAL GAS COMPANY

assured of 100% reliable microwave communications with . . .

AMAZING



MICRO POWER

Heart of the microwave communications link between the Williams and the Seligman, Arizona, compressor station of El Paso Natural Gas Company is a United States Motors Corporation Micro Power. The engine of the conventional Micro Power in this case is replaced by a DC motor which is fed from the station batteries, from which all supervisory and telemetering equipment operates. Should the AC commercial power fail, the Micro Power continues to supply the microwave without voltage drop, droop, or break. Micro Power operates from, but isolates the microwave from the commercial power and removes the bad effects of voltage dips and peaks.

MICRO POWER operates with the main source of power. There are no transfer switches, no starting batteries with Micro Power. Available in 1500, 3000, 5000 and 10,000 watt capacities; for gas, gasoline or diesel engine emergency drive. For complete information, write . . .

UNITED STATES MOTORS CORPORATION

112 West Fifth Avenue • OSHKOSH, WISCONSIN

CATHODIC PROTECTION EXPERTS

choose *JAQUES Hydraulic* EARTH AUGER

for Greater

SPEED, ECONOMY!

Experienced corrosion engineers *(such as Cathodic Protection Service of Houston and Tulsa)*, select JAQUES Hydraulic Earth Augers as the most effective tools for installing anodes in any kind of soil, faster, more economically. JAQUES jeep-mounted KV-515 can be quickly positioned for high-speed drilling of anode holes up to 12" diameter, up to 15' deep. JAQUES TJ-254 mounts on standard trucks, digs holes to 48" diameter, up to 25' deep, in hardest soil or rock. For FREE demonstration or literature with detailed specifications, write today to . . .

TEXOMA ENTERPRISES, INC.

JAQUES Jeep-Mounted KV-515 in actual operation by Cathodic Protection Service in Houston, Texas, drilling one in a series of 25, 9½' anode holes for protection of 30-inch steel pipeline.

HIGHWAY 75 NORTH
SHERMAN, TEXAS

Get MAXIMUM Cathodic Protection ECONOMICALLY with *JAQUES!*

Pipe Line Chemical Co. Acquires Sanco Products

The Pipe Line Chemical Company of Dallas has purchased the trade names, formulations, inventories and sales rights to products that have been manufactured and distributed by Sanco Industries in the past.

Al Stultz, formerly manager with Sanco Industries, will be manager for Pipe Line Chemical Company with complete charge of these sales.

CLASSIFIED ADVERTISING

SALESMAN WANTED

Well-established successful firm has opening in an expanding sales department for young man looking for an opportunity in sales work. Must be college graduate, not over 33, in good health, ambitious and not afraid of work. Oil industry experience desirable. The man we are looking for will be trained at home office before moving into sales work on basis of salary plus commission incentive and traveling expenses. Our own personnel know of this advertisement. Your reply will be confidential and should be sufficiently complete to merit contacting you for an interview. Address Box 56-P, PIPE LINE INDUSTRY, Houston, Texas.

DRAGLINE MATS

Any Length, Width or
Built to Specifications

We build them a little better
For a little less

STRICTLY HARDWOOD
Also LUMBER AND PILING

KENT PILING CO., INC.

T. W. "TOM" KENT, PRESIDENT
Phone Day: Amite 2641 — 2644
Night: 8454
FLUKER, LOUISIANA

WELDING CABLE

AT LOW PRICES

CUT-TO-LENGTH

#8 . .	7½¢ ft.	#1 .	24¢ ft.
#6 . .	9½¢ ft.	#1/0 .	29½¢ ft.
#4 . .	12½¢ ft.	#2/0 .	36½¢ ft.
#3 . .	15½¢ ft.	#3/0 .	46¢ ft.
#2 . .	19½¢ ft.	#4/0 .	56¢ ft.

5% Discount For Full Reels of 500 ft. and 1000 ft.

We Pay Freight on 300# or More
Add 10% For Orders Under 100 ft.

Call Universal for all Electric Wire and Cable Needs

Write for our 1960 Stock Sheet

UNIVERSAL WIRE & CABLE CO.

2935 N. Paulina St. Chicago 13
Branch Warehouses
Houston, Los Angeles and Denver

WHO'S MEETING WHERE

May

Instrument Society of America, Summer Instrument-automation conference and exhibit, Civic Auditorium and Brooks Hall, San Francisco, May 9-12.

AGA Operating Section, joint distribution and transmission conference, Roosevelt and Jung Hotels, New Orleans, May 9-13.

American Society for Metals, southwestern metal congress and exposition, Dallas, May 9-13.

University of Kansas, gas conditioning institute, National Guard Armory, Liberal, Kan., May 11-12.

ASME, oil and gas power conference and exhibit, Muehlebach Hotel, Kansas City, Mo., May 22-26.

National Telemetering Conference, Miramar Hotel, Santa Barbara, Calif., May 23-25.

International Instruments, Electronics and Automation Exhibition, Olympia, London, May 23-28.

American Right of Way Association, annual seminar, Shoreham Hotel, Washington, D. C., May 24-26.

Pacific Coast Gas Association, accident prevention and transmission conference, Hotel Utah, Salt Lake City, May 25-27.

International Pipe & Pipelines Exhibition, Earls Court, London, May 30-June 2.

June

Appalachian Underground Corrosion Short Course, West Virginia University, Morgantown, W. Va., June 1-3.

Fifteenth Annual Short Course in Gas Technology, Texas College of Arts and Industries, Kingsville, Texas, June 1-3.

Kentucky Oil & Gas Association, annual meeting, Phoenix Hotel, Lexington, June 2-3.

ASME, summer meeting, Statler Hilton Hotel, Dallas, June 5-9.

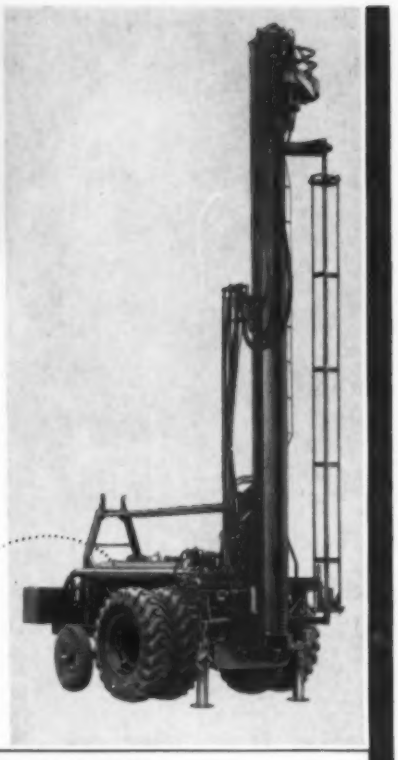
AIEE, summer general meeting, Atlantic City, N. J., June 20-24.

Institute of Radio Engineers, fourth national convention on military electronics, Sheraton-Park Hotel, Washington, D. C., June 27-29.

July

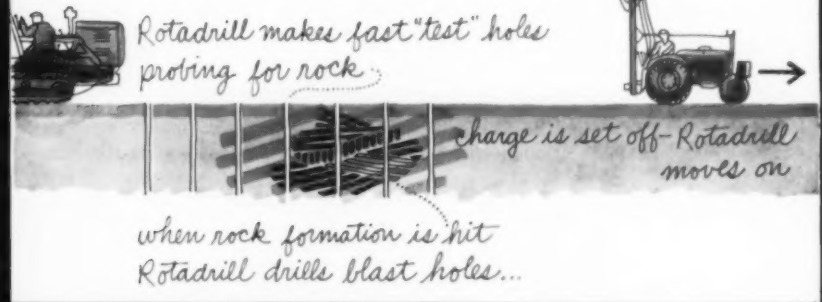
ASCE, conference on civil engineering education, University of Michigan, Ann Arbor, Mich., July 6-8.

SCHRAMM ROTADRILL SPARKS BIG COST-CUTTING IDEA IN PIPELINE INDUSTRY



❶ to begin with— Rotadrill is a rugged, self-contained, self-propelled drill rig

❷ idea (now in use) is to run a Rotadrill ahead of trencher on pipeline jobs


Rotadrill makes fast "test" holes probing for rock
charge is set off- Rotadrill moves on
when rock formation is hit Rotadrill drills blast holes...

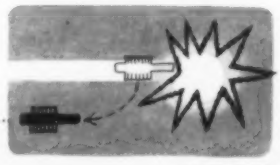
❸ trencher follows without interruption . . .

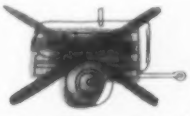
❹ Rotadrill ends:

trencher downtime when rock is encountered

moving trencher away while crews blast

moving a compressor along with the trencher to drill blast holes





Schramm

ROTADRILLS and ROTATOOLS

740 North Garfield Ave., West Chester, Pa.

Get the full story on Schramm P-41 Rotadrill for your pipeline operations. Write for Catalog DM58-4 and name of your nearest Schramm Dealer-Demonstrator.

ONLY THE NEW TD-25 "BOOM" GIVES YOU

Now—International Superior announces the new TD-25 sideboom.

Now, you get the pipe-handling wallop of 230 direct-started, turbocharged Diesel hp. *Plus* the exclusive teamwork of "live track" Planet Power-steering and Hi-Lo power-shifting!

"Live power" on both tracks full time, with fingertip speed control of either track, lets you turn smoothly with the pipe load, upgrade or down. Load-limiting "dead-track drag" is eliminated. And you can power-shift the "25" up or down, on-the-go, in forward or reverse. *TD-25 standard equipment gives you pipe-handling maneuverability that no king-sized clutch-steered crawler can deliver, even with costliest attachments!*

The "25" is platformed on new 7-roller tracks with double-box-beam frames. This design assures super undercarriage strength for slam-bang conditions—*plus* mud-and-mountain beating flotation and stability. Heavy-duty TD-25 Dura-Rollers defy the pipelining "grind"—with the industry's thickest shells, to

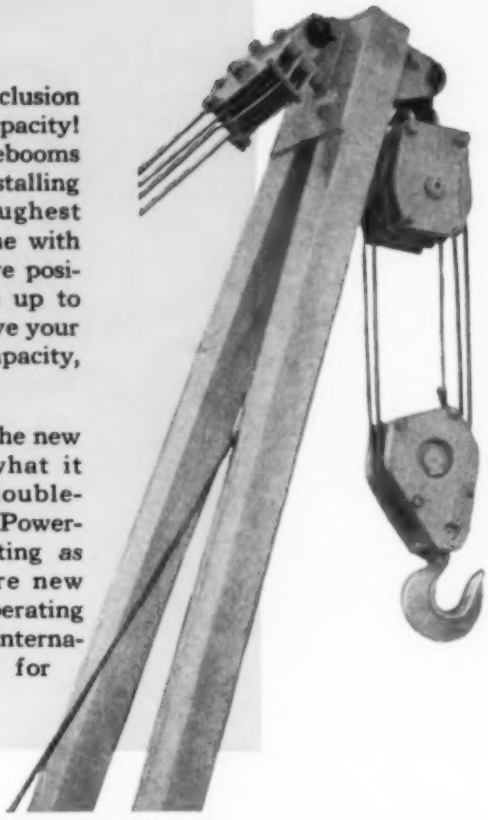
Planet Power-steering and

New International Superior TD-25 Sideboom lifts 130,000 lbs. at 4' overhang. Six quick-change counterweights with big lifting eyes save up to 90% on time needed to adapt rig for any "lift" or "carry." Unit is powered by the 6-cylinder, direct-start DT-817 Diesel—developing 230 high-torque hp!

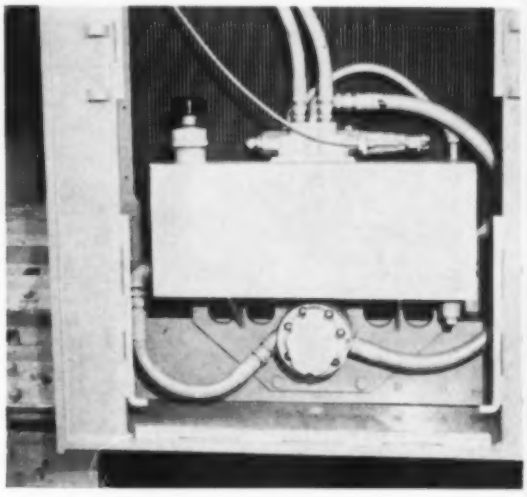
prevent flexing—positive grit-exclusion—and 1,000-hr-interval lube capacity!

No wonder new TD-25 sidebooms can "show other makes how," installing difficult sections—beating toughest weather and terrain—saving time with accurate lowering and gate-valve positioning—leap-frogging at speeds up to 7.7 mph. New "25" sidebooms give your whole spread new pipe-laying capacity, all the way!

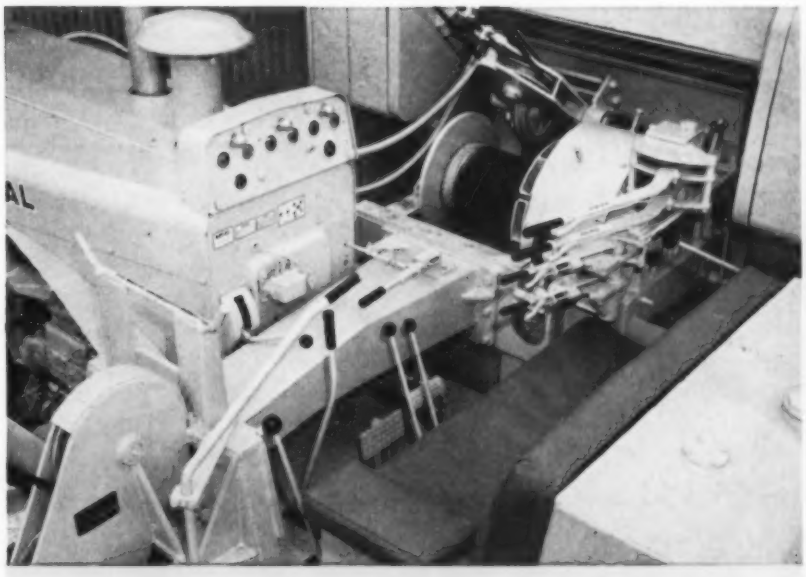
Power-steer and power-shift the new TD-25 sideboom—compare what it means to get the exclusive, double-barreled advantages of Planet Power-steering and Hi-Lo power-shifting *as standard equipment*. Compare new TD-25 sideboom capacity, operating ease and economy. See your International Superior Distributor for a demonstration.



New TD-25 sideboom hydraulic system features increased capacity, and exclusive new accessibility. Step-up in hydraulic power speeds boom action—while retaining famous International Superior sideboom slip-proof, inch-close, pipe-handling accuracy. To service this protected hydraulic system, simply unlatch radiator-guard door!



d power-shifting, as standard!



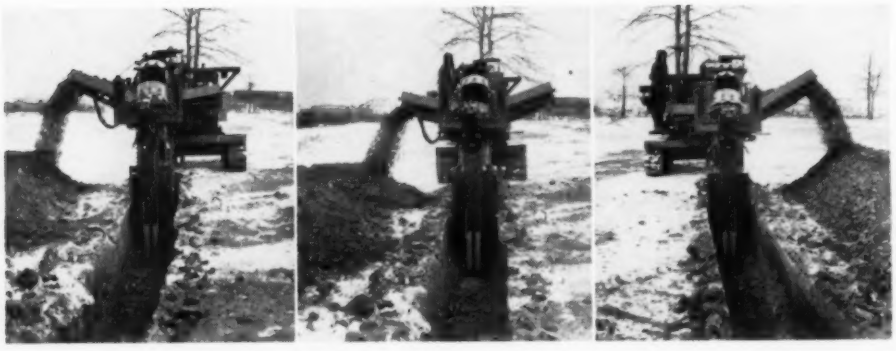
Note the safe, comfortable, production-practical operator's compartment! Read-easy instrument panel is at eye level. Reach-easy boom-control levers are vertically stacked. New fleeting sheave is provided over boom drum—another big contribution to high availability and long cable life!

International Harvester Company, Chicago 1, Illinois

INTERNATIONAL®

SUPERIOR

What's New in EQUIPMENT



Ditching Machine

A new ditching machine featuring instant lateral positioning and tilting of its digging wheel has been introduced by Cleveland Trencher Company.

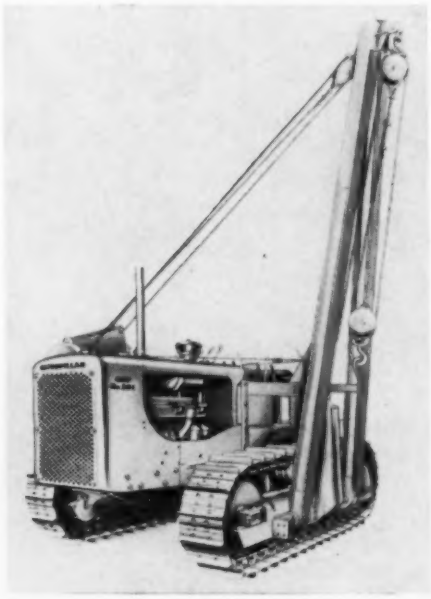
It cuts vertical trench on side slopes and in similar conditions where one crawler track is on a higher level than the other. The JS-30 has lateral shifting which permits trencher to dig the edge of a 24-inch wide trench 5-inches outside wither track, permitting trench to be dug flush with parallel pavement, curbs and sidewalks. It also excavates short runs of extrawide trench, bellholes, etc., up to 6-foot maximum width without lateral repositioning of its crawler.

As a result of its tilting range of 14 degrees, the JS-30 can cut vertical trench on side slopes, adjacent to curbing, etc., without cribbing. Hydraulic power tilt adds 7 inches to the outside cut of the digging wheel, and combined with lateral shift, permits digging trench virtually flush with fences, trees and other above-ground obstructions.

The V-shaped conveyor is also employed on the trencher JS-30. It permits higher and farther spoil discharge and higher heaped loads on the conveyor belt. Automatic conveyor positioning permits the operator to place spoil where required.

The crumbling shoe can be raised or lowered to allow digging at sidewalks and other obstructions without extra clearance for shoe. Operator has choice of four-wheel speeds and 12 individual crawler speeds.

For more data, circle **No. E1** on Readers' Service Card, last page this issue.



Greater Lift

Caterpillar Tractor Co. announces development of a new pipelayer with greater lifting capacity, No. 561 Series B, which will replace the MD6 pipelayer. Capacity of the 561 is 38,800 pounds at four foot overhang with 5,000 pounds adjustable counterweights.

The pipelayer is powered by a new compact engine which delivers 93 flywheel horsepower. Streamlined air flow and more efficient "breathing" is provided by the intake manifold being an integral part of the cylinder head. The No. 561 also has a new unit fuel pump housing, permitting easier servicing of the entire assembly and a new design governor allows faster response to varying load conditions.

Controls on the new pipelayer permit short, direct arm movements by the operator. Steering clutches are hydraulically boosted; a forward reverse lever and conveniently located gear shift levers allow quick arm movements in selecting speed and direction of travel.

(This item supplements Caterpillar Tractor Co. data on pages 76-97 of the Pipe Line Catalog, Second Revision.)

For more data, circle **No. E2** on Readers' Service Card, last page this issue.

Data Processing System

Designated the "G-20," a new electronic data-processing system has been introduced by Bendix Aviation Corp. Capable of 45,000 floating points operations per second, the system has the ability to solve very large scientific and data processing problems at high speeds. The solid-state, highly automatic unit leases for less than $10,000 per month.

The system can be assembled in an exceptionally wide range of sizes to meet different needs. A large number of subordinates may be used, for numerous jobs. The input-output equipment offered includes magnetic tape units that read and write at 120,000 digits per second and 600 to 1,250 line-per-minute printers.

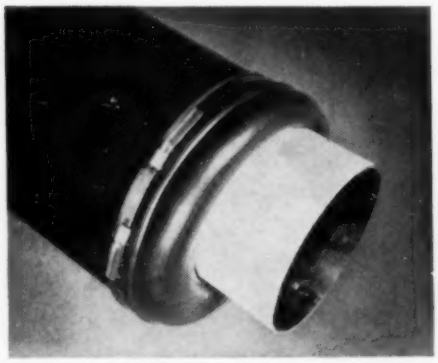
For more data, circle **No. E3** on Readers' Service Card, last page this issue.

Coal-Tar Primer

A quick-drying primer for coal tar enamels has been developed by Reilly Tar & Chemical Corporation. The new primer, Reilly Redhead, has a translucent red color that permits visible detection of areas missed in cleaning, areas not covered by the primer or areas not covered by the enamel. It dries to the touch in 5 or 10 minutes at application to metal surfaces in 70°F with relative humidity under 70 percent.

It has a coverage rate of 500 to 800 square feet per gallon.

For more data, circle **No. E4** on Readers' Service Card, last page this issue.



Flexible Casing Seal

A new flexible casing seal, the U-Seal has been developed by T. D. Williamson, Inc. With fungus and bacteria retardent added, the seal provides "maximum flexibility" for any crossing installation. It maintains its seal regardless of the change in pipe position in relation to the casing; up, down, sideways, in or out.

Two stainless steel bands hold the U-Seal firmly in place. A screwdriver is the only tool needed to tighten the bands. It can be installed in two ways—the U-shape with shorter band "inside," or with shorter band on the "outside" in the Z-shape. Its flexibility permits installation on wide ranges of coating thickness for any given pipe size.

For more data, circle **No. E5** on Readers' Service Card, last page this issue.

Locate Underground Shorts

To locate underground shorts in pipe lines, a new Pearson type detector is announced by Tinker and Rasor. It can be used to locate discontinuities in the coating of buried pipe lines and to locate electrical contacts on the line. All findings are accomplished without uncovering pipe.

For more data, circle **No. E6** on Readers' Service Card, last page this issue.

CLOSE TO HOME, PUMP-WISE AND SERVICE-MINDED!

—Your Gaso Distributor

Edmonton, Alberta

Casper, Wyoming

NEW YORK

Evansville, Ind.

TULSA, OKLAHOMA

Brookhaven and Tinsley, Miss.

Shreveport, La.,

Wichita Falls, Texas

Odessa, Texas

Houston, Texas

Bakersfield, Cal.

Long Beach, Cal.

Farmington, N. M.

GASO DISTRIBUTORS BRING GASO SERVICE TO YOUR BASE OF OPERATIONS

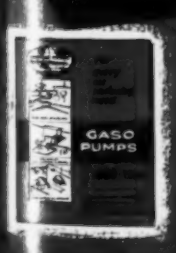
We screen and pick our distributors with the utmost care. We bring their organizations to Tulsa for thorough training in oil-industry pumps and their application. We insist that they carry stocks of Gaso Pumps and parts.

Result: Complete Gaso service at your doorstep. Time-saving. Convenient. Still another explanation of the worldwide preference for Gaso Pumps.

GASO PUMP & BURNER MFG. CO.
FIRST and LANSING STS., TULSA, OKLAHOMA
EXPORT OFFICE: 2712 EMPIRE STATE BLDG.
NEW YORK, N. Y.

GASO PUMPS

for every oil industry need



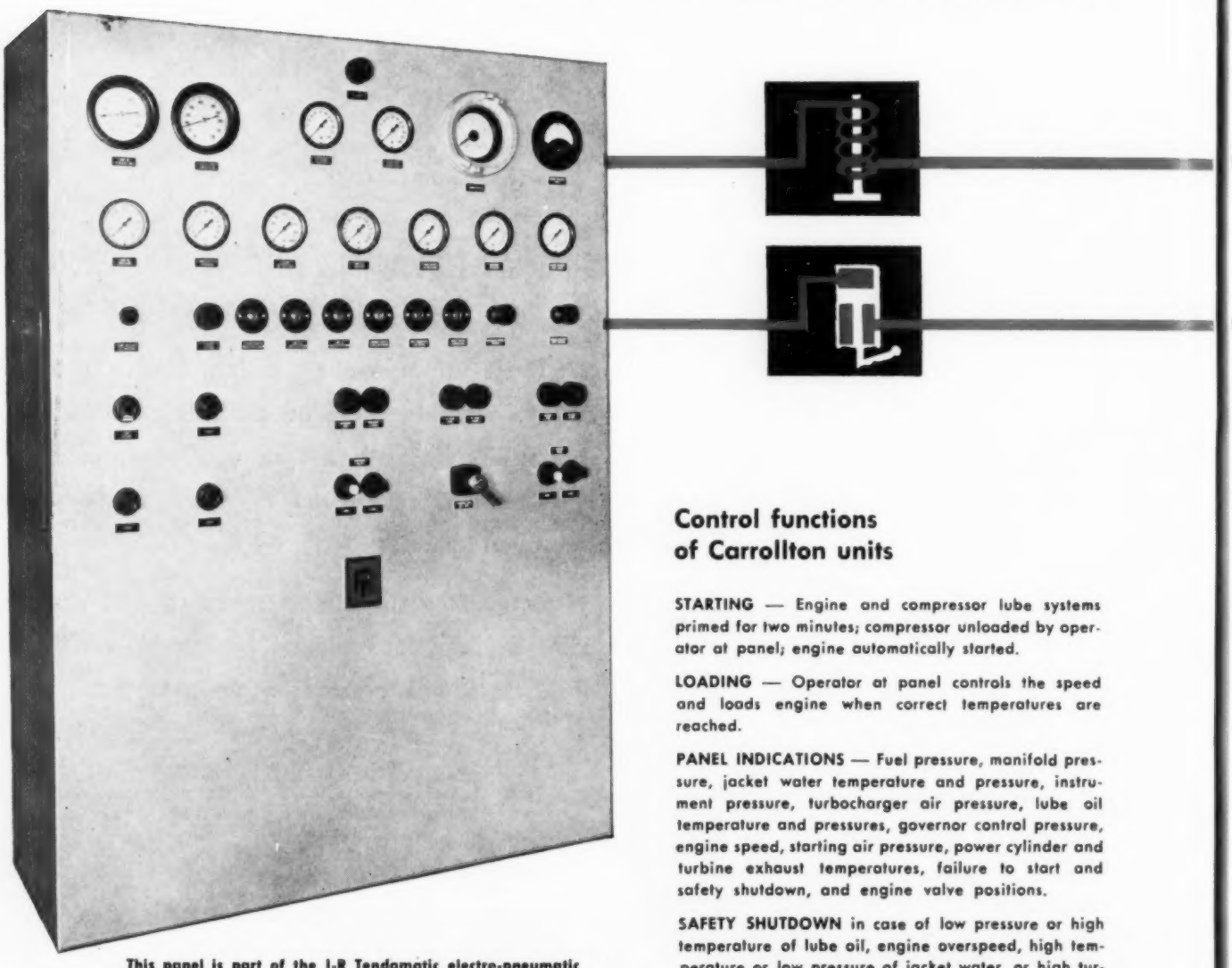
DISTRIBUTORS

Farmington, N. M. – Gaso Pump & Burner Mfg. Co. • Shreveport, La., Odessa, Texas, Brookhaven and Tinsley, Miss. – W. L. Somner Company • Houston, Texas – Texas Pump & Compressor Company • Wichita Falls, Texas – Pump Engineering Co. • Evansville, Ind. – Hague Equipment Co., Inc. • Long Beach and Bakersfield, Cal. – Power Pumps, Inc. • Casper, Wyoming – Lufkin Foundry & Machine Co. • Edmonton, Alberta – Lufkin Machine Co., Ltd.

AT TENNESSEE GAS

NEW Tendamatic®

ELECTRO-PNEUMATIC



This panel is part of the I-R Tendamatic electro-pneumatic system which provides automatic control and protection of KVS gas-engine compressors at the Carrollton station.

Control functions of Carrollton units

STARTING — Engine and compressor lube systems primed for two minutes; compressor unloaded by operator at panel; engine automatically started.

LOADING — Operator at panel controls the speed and loads engine when correct temperatures are reached.

PANEL INDICATIONS — Fuel pressure, manifold pressure, jacket water temperature and pressure, instrument pressure, turbocharger air pressure, lube oil temperature and pressures, governor control pressure, engine speed, starting air pressure, power cylinder and turbine exhaust temperatures, failure to start and safety shutdown, and engine valve positions.

SAFETY SHUTDOWN in case of low pressure or high temperature of lube oil, engine overspeed, high temperature or low pressure of jacket water, or high turbine exhaust temperature. If emergency shutdown occurs, horn sounds and pneumatic indicators show reason at panel; fuel gas is shut off and later ignition is grounded.

NORMAL SHUTDOWN — Operator at panel actuates automatic sequence which unloads, slows and stops unit. Lube system runs for two minutes longer.

PIPELINE COMPANY. . .

compressor control features operation

for convenience and economy in starting and normal shutdown sequence control

for safety and dependability in normal running and emergency shutdown control

At the Carrollton, Ohio, station of Tennessee Gas Pipeline Company, a division of Tennessee Gas Transmission Company, four 2000-hp Ingersoll-Rand KVS gas-engine compressors are operating under the constant vigil of a new achievement in automatic control systems.

This new I-R Tendamatic control installation combines the advantages of both electric and pneumatic operation in a single automatic control and protection system. Engine startup and normal shutdown are accomplished by electrical sequence control, permitting the use of compact electric timers, relays, etc. Once the compressor is loaded and on the line, the pneumatic system takes over the job of monitoring, indication and automatic emergency shutdown.

Therefore, the control and protection of the engine-compressors are independent of the electrical system, and a power failure would have no effect on successful operation.

Tendamatic systems can be supplied to meet any requirements – for remote, semi-remote, local, microwave, two-wire, multiple-wire, electric, pneumatic or hydraulic operation or in combinations. For more information, call your I-R representative.

Ingersoll-Rand 2000-hp KVS 4-cycle, V-angle engine-compressors at the TGP Carrollton station.

Only I-R compressors have Tendamatic control

Ingersoll-Rand

1A6 **11 Broadway, New York 4, N. Y.**

Pipe Slings

A new line of slings has been introduced for use in a wide variety of industrial and pipe line applications. Designed to lift without damage, the slings consist primarily of parallel high-strength aircraft cables covered with rubber garments secured at the ends by special attachments.

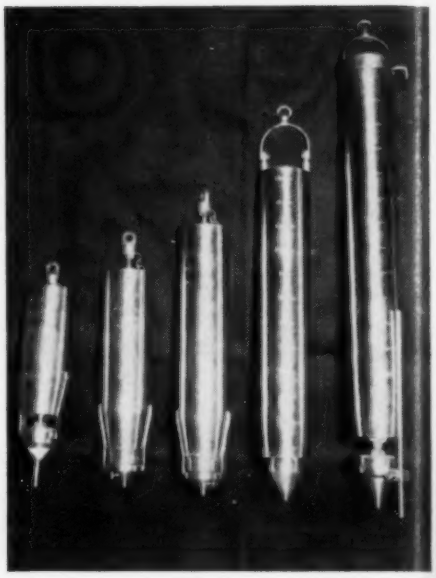
The Colorado Fuel & Iron Corporation slings are flexible, light weight and are comprised of two pipe line models and five industrial models, each designed to be used in basket and choker hitch.

(This item supplements Colorado Fuel & Iron Corp. data on pages 94-95 of the Pipe Line Catalog, Second Division.)

For more data, circle **No. E7** on Readers' Service Card, last page this issue.

Tank Sampler

P & M Company announces availability of a tank sampler which gages tank and obtains sample in one operation. It adapts to regular gageline; no ropes or chains to strip of liquid before reusing. This 30-ounce unit is 8½ inches long with a 2-inch barrel. It gathers an 8-ounce sample. It takes less than a minute to take a sample and a reading.



For more data, circle **No. E8** on Readers' Service Card, last page this issue.

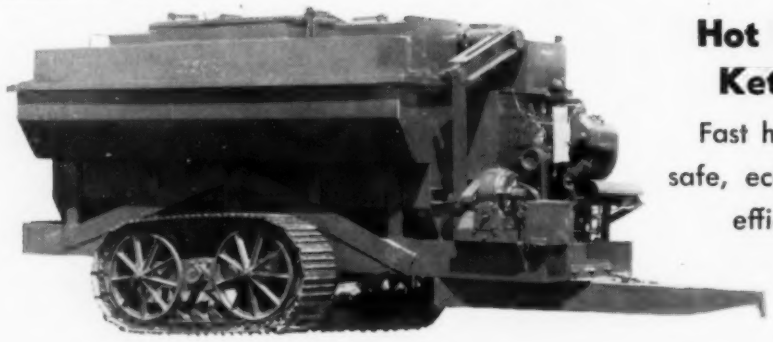
PEMCO PRODUCTS for PIPE LINES

PIPE REFORMING CLAMPS

Individually controlled pressure points. Pipe can be aligned to valves and flanges without wedges or hammering. Sizes through 72".

PEMCO PIGS

Sizes:
2" through 72"

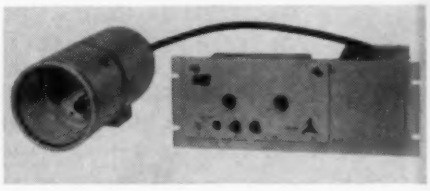


Hot Dope Kettles

Fast heating, safe, economical, efficient

PIPELINE EQUIPMENT MANUFACTURING CORP.

2525 MAGNET STREET, HOUSTON, TEXAS



Television Camera

Built to withstand weather, shock, vibration, salt spray and other extremes of environment without auxiliary protective housing, Dage Television Division of Thompson Ramo Wooldridge, Inc., announces its new television camera.

Totally transistorized, the camera weighs only 15 pounds, is 16 inches in length and 6⅞ in diameter. It employs modular construction, using plug-in transistorized printed circuit modules, each representing a particular function of the camera.

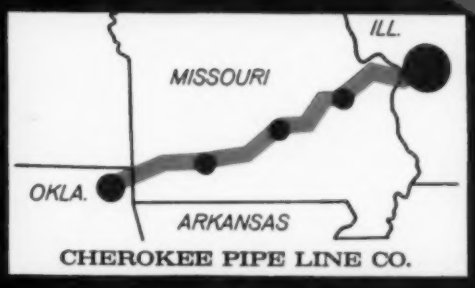
For more data, circle **No. E9** on Readers' Service Card, last page this issue.

Rough Terrain Truck

Capable of climbing over 3-foot walls and manueuverable in rough terrain, the "Flec-Trac" six-wheeled truck has been introduced by Clark Equipment Company's Industrial Truck Division.

Manufactured to perform such functions

PUSH BUTTON PIPELINE



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SIE, through solid state electronics brings you the latest developments in remote supervision, computing and control.

- Automatic Sequencing and Load Control
- Data Logging
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Designed for long life and reliability with highest data density and scan rate of any system . . . by

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146 ACRES OF ELECTRONICS

as traversing a 45 degree slide slope, crossing rivers, drive through mud, snow and sand or marshland and speed 56 mph over highways the truck was designed by the firm E.Meili of Schaffhausen, Switzerland.

Unusual operating characteristics of the model result from construction which permits any one of three pairs of wheels to be raised off the ground. Articulation is controlled hydraulically so that the vehicle can assume a "swayback" position, with front or rear wheels higher than center, or an "arched back" with center wheels higher. All six wheels are drive wheels. All wheels can be made to turn together regardless of traction conditions at individual wheels. Clark is testing two models, one is one-ton capacity and weighs 3,300 pounds with a wheelbase of 86.5 inches. The other is two-ton capacity, and weighs 7,100 pounds with wheelbase of 112 inches.

For more data, circle **No. E10** on Readers' Service Card, last page this issue.

Pipe Locator, Tracer

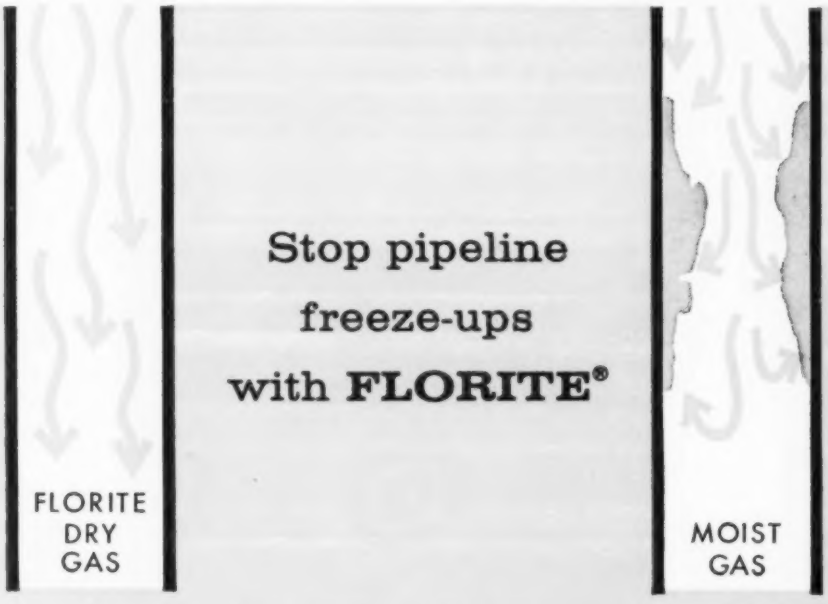
Development of a new pipe and conduit locator has been announced by Sharpe Instruments of Canada with a new transistorized low frequency tuned circuit tracer. The locator tracer uses "tuned circuits" in transmitter and receiver to cancel out signal killing interference. Signal strength in the phones is maintained at a high level, even miles from the transmission point.

The receiver unit is fully transistorized and can be carried in the shirt pocket; battery drain is very low. Liquid seal head

phones are available as an optional extra. The tracer enables an engineer to locate, trace and triangulate underground pipes anywhere, even those that run parallel to power lines and similar audio-frequency producing sources.

A ground stake and pipe or conduit to be traced, are connected to the transmitter. It is switched on, tuned to the highest signal. The receiver is then switched on, tuned to audio frequency of transmitter. Retuning is unnecessary once receiver and transmitter are set to same frequency.

For more data, circle **No. E11** on Readers' Service Card, last page this issue.



Stop pipeline freeze-ups with **FLORITE®**

Florite is an inexpensive desiccant that saves money and increases pipeline efficiency because it eliminates deposits caused by icing at low temperatures. Florite keeps the effluent dew point at a low, safe level so hydrates do not form in pipes and valves. The turbulence around hydrate deposits is eliminated, pipeline efficiency and capacity are retained and pressure-drop is reduced to a minimum.

Florite absorbs water instantly from gas. In fact, it can absorb up to 20% of its weight and can be regenerated in place by heating to 350°F. It is nonswelling and will not disintegrate. If you wish additional information about the drying properties of Florite, mail the handy coupon.

FLORIDIN COMPANY

Fuller's Earth • Activated Bauxite • Synthetic Adsorbents

Sales Offices: P. O. Box 989, Tallahassee, Florida • 375 Park Avenue, New York 22, N. Y. • 8000 Bonhomme Avenue, St. Louis 5, Mo. • 292 Meadows Bldg., Dallas 6, Texas

Floridin Company, P. O. Box 989, Tallahassee, Florida

Gentlemen:

☐ *Please give me more information on FLORITE.*

Name_____ **Position**_____

Company_____

Address_____

City_____ **Zone**____ **State**_____

Digital Encoder

Higher rotation speed, increased reliability and longer life are primary features of a new magnetic technique for shaft position-to-digital encoders developed by Librascope Division, General Precision, Inc. The noncontact technique generates digital signals representing input shaft position by altering the magnetic state of ferrite readout cores in accordance with a coded pattern cut into the surface of a ferrite disc driven by the shaft.

The magnetic encoders can be used in all applications where it is desired to convert a mechanical analog quantity to a form suitable for use in digital computation.

For more data, circle **No. E12** on Readers' Service Card, last page this issue.

Model TBR-3

Model TBR-5 — Also available in 10-gal. size Model TBR-10

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THE Tall Boy

with the "TOWER BASE"

Still Highest Quality!

Set it on the ground, rig floor, or any flat surface. Useable anywhere! GOTT'S new "Tower Base"—engineered to provide a higher faucet that permits cups to be filled without holding the cooler or providing a stand. New convenience for "on the job" or "in the field"!

The Gotkool "TALL BOY" is another superior product by H. P. GOTT Mfg. Co., famous for 41 years for GOTKOOL water cans and coolers. First with the double-wall thermo design! Sweat-soldered seams! Soldered faucets! Only GOTT brings you so many exclusive features for longer service, rugged wear! Of course, standard models are still available as always.

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WINFIELD, KANSAS

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Distributor in the Southwest for:

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for land use
(Manufactured by American Coating Supply Co.)

MANUFACTURERS OF:

FORMULA 291
Skin Saver

*Fieldjointer Patent No. 2763047

"serving all pipelines"

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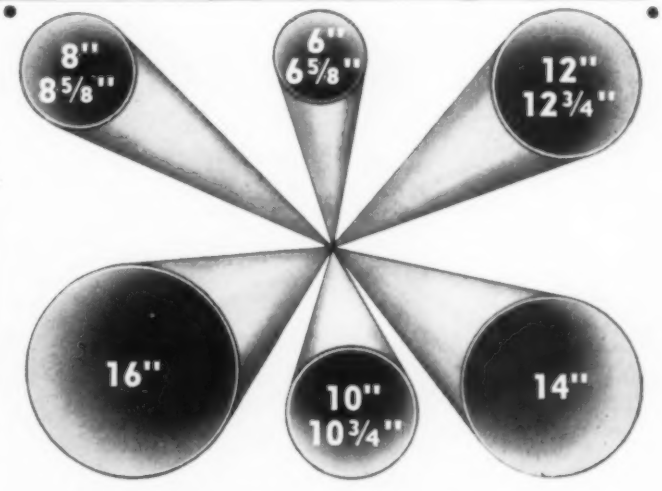


NEW high frequency, resistance welded pipe

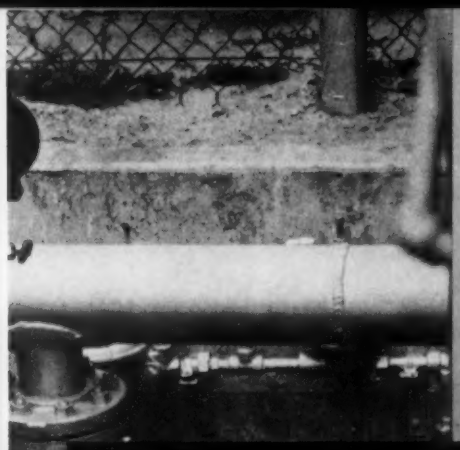
If you want a closer source for pipe that meets the highest standards of the industry, better talk to Valley. New resistance welding and process control facilities assure you of the quality you demand. Ideal as line pipe for petroleum, gas, water, etc. Surface casing also available. Special wrappings and coatings.

Sizes: 6" 6⅝" 8" 8⅝" 10" 10¾" 12" 12¾" 14" 16" in wall thicknesses to .219.

Write or call Steel Pipe Division

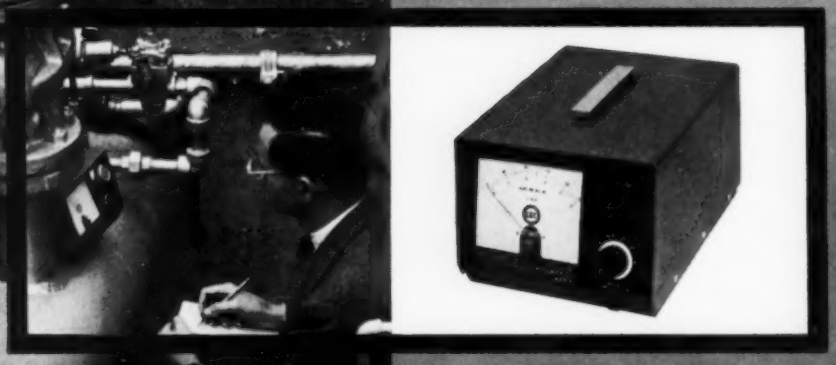
VALLEY MANUFACTURING COMPANY
VALLEY, NEBRASKA

For more data on advertised products, use Readers' Service Cards, last page.



ON STREAM... ON SPEC

CEC Moisture Monitors detect 1 part per million



Plagued with water contamination? CEC's complete line of Moisture Monitors makes possible continuous safeguarding of both gas and liquid streams—instruments accurately and reliably measure trace moisture to less than one part per million water by volume.

PORTABLE MOISTURE MONITORS
are suitable for laboratory or field use. They can be used with or without line power, provide continuous readout on a large front-panel meter. For further information contact your nearby CEC sales and service office, or write for Bulletin CEC 1834-X3.

Analytical & Control Division CEC

CONSOLIDATED ELECTRODYNAMICS / pasadena, california

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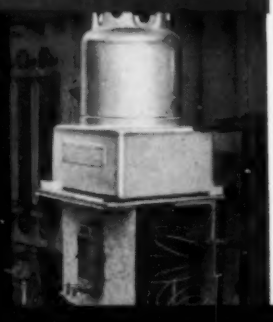
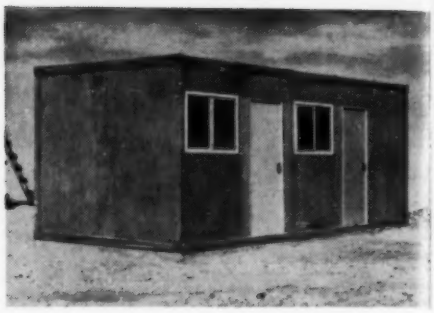
CEC PROCESS MOISTURE MONITORS
for gas and liquids measurements operate unattended—are suitable for closed-loop control. The Analyzer unit can be installed in Class I, Group D, Division 1 hazardous locations. Remote controls regulate instruments from up to 500 feet. Bulletins CEC 1845-X26 and 1856-X6





Prefabricated Buildings

Designed for living accommodations in isolated areas, the Preline P. B. 5 buildings have been introduced by J. E. Lesser & Sons Ltd. The prefabricated units are supplied with floor, designed to be laid on level ground. They are available mounted on steel skids for rapid transportation on low-loading trucks.

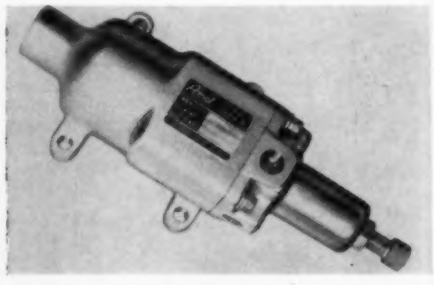
A 24-foot by 12-foot plywood building can be erected or dismantled by unskilled labor in two hours. It can be assembled without the aid of mechanical handling equipment. All joints are sealed with PVC foam to prevent dust infiltration; all electrical outlets are located in main entrance-door panel, and doors and windows are provided with flyscreens and all fittings.

For more data, circle **No. E13** on Readers' Service Card, last page this issue.

Bearing Bolt

A high strength bearing bolt for structural uses has been introduced by Lamson & Sessions Co. and will be handled by U. S. Steel Supply. Rows of specially formed knurls mark the shank between the bolt head and the threaded section. Knurls are set into the shank in a spiral pattern to reduce the driving load, and also to produce a body-bound fit when the fastener is driven or wrenched into place. The bolt head is shaped like a driven rivet to permit driving with standard tools. It is made of heat treated carbon steel.

For more data, circle **No. E14** on Readers' Service Card, last page this issue.



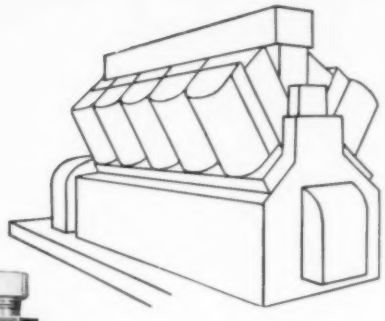
Vibration Valve

Amot Controls Corporation announces its Model 2,900 vibration valve employed as a 2 or 3-way, snap acting, non-overlap vibration monitoring valve on pneumatic or hydraulic control systems to 80 psi, it can be used on engines, compressors, fans and other rotating or reciprocating equipment.

Sensitivity of the valve is manually adjustable and it is sensitive to vibration from any direction in the plane perpendicular to its longitudinal axis.

For more data, circle **No. E15** on Readers' Service Card, last page this issue.

Specify AMOT Controls ....they give your engines Maximum Protection!

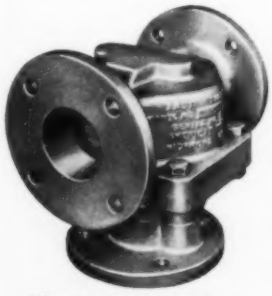


Temperature Valve
3-Way Control
Model 4021

The AMOT Model 4021 Temperature Valve features a balanced, 3-way type of action suitable for pilot pressure control in any control system. Actuating temperature settings from 95 to 235° F. Available also with extensions and stainless steel well.

Another new AMOT product recently developed for the engine industry is the Model 4023 High Pressure Valve. Suitable for pressures from 250 to 6000 psi, the 4023 also has balanced 3-way action.

High Pressure Valve
3-Way Control
Model 4023



Thermostatic Valves
½" to 6" Pipe Size
Model B

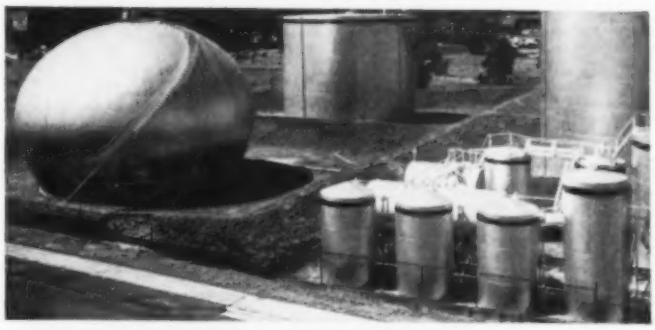
The AMOT "tamper proof" Thermostatic Valve has become Industry's STANDARD for Engine, Compressor and Process temperature control. Available in ½" to 1½" in cast iron or bronze; 2" to 6" in cast iron, ductile iron or bronze.

AMOT CONTROLS CORPORATION

Representatives in Principal U.S. Cities.

FIRST ST. & NEVIN AVE. RICHMOND, CALIFORNIA

Now! More Dead Weeds and Brush per Dollar



with **UROX®** WEED KILLER

One Application Gives 8 to 18 Month Control!

Here's the weed killer you can *positively depend on* to wipe out weeds and brush faster, easier, at lower cost and for a longer time than you ever thought possible. Urox weed killer effectively handles weed killing jobs along pipelines, on tank farms, around refineries and pumping stations, where weeds and brush are a constant fire hazard. In all these places, *just one application of Urox weed killer will remain effective for as long as 8 to 18 months!*

Longer lasting! Saves time and money! Urox weed killer has a cumulative effect on weeds and brush. Its herbicidal action can thus be extended from one year to the next with light booster doses. As smaller amounts are used over a period of time, you realize substantial savings.

Easy to use! *Liquid Urox* weed killer is ideal for spraying large overgrown areas. It won't clog spray nozzles or strainers! Won't precipitate out in the tank! Stays in solution perfectly! *Granular Urox* weed killer is the convenient inexpensive way to treat small weed-infested areas. Can be applied easily with any mechanical or hand-operated spreader.

New Urab* weed killer kills deep-rooted brush and weed trees! If you have problems with tough, deep-rooted weeds, brush or weed trees, *New Urab Weed Killer* is just what you're looking for. Urab weed killer actually *penetrates soil* to kill deep roots. Does what no other herbicide can! Supplied in liquid and granular forms.

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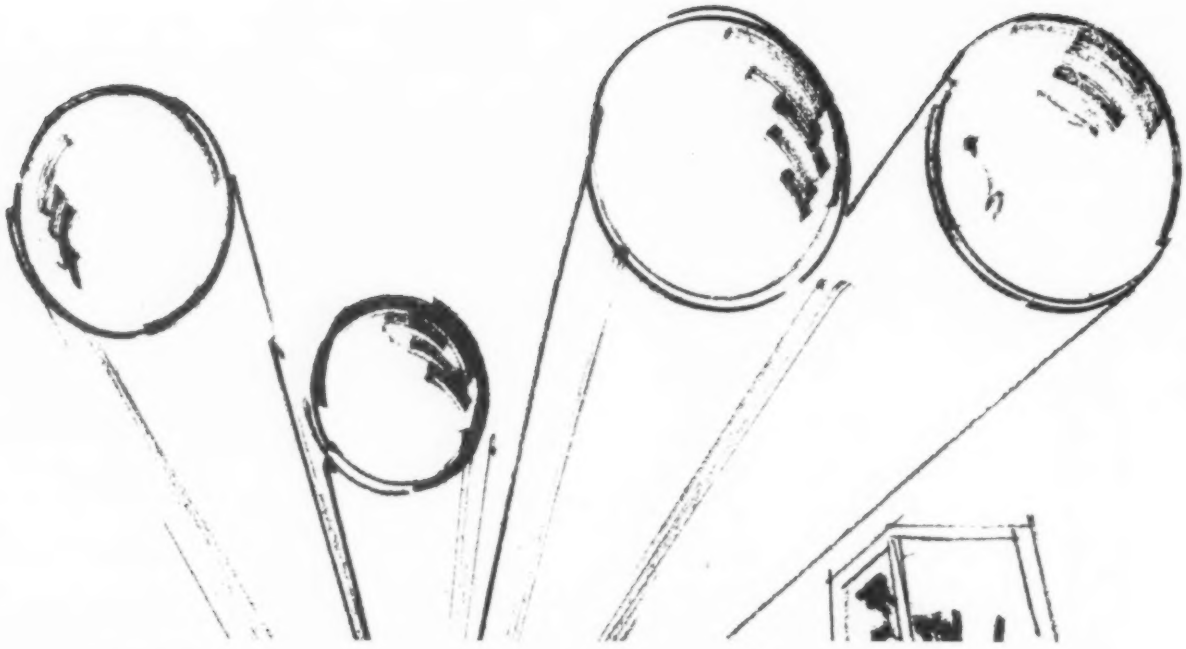


Wherever pipe lines go . . .

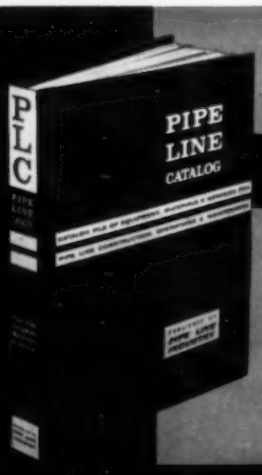
The only equipment-materials-service catalog prepared exclusively for the industry, PIPE LINE CATALOG is a library of purchasing information. Indispensable to any purchaser or specifier – operating or field executive, superintendent, foreman, engineer, purchasing agent – the catalog has data from almost 200 companies selling to the industry.

Thousands of products and services are described in this handy, one-volume, cross-indexed reference work of complete and condensed suppliers' catalogs. Finding what you want when you want it – and com-

. . . Pipe Line Catalog goes!

paring it to other products – is easy with PIPE LINE CATALOG . . . one of the biggest time and money savers in the industry.

Forget the frustrating, time-consuming chore of maintaining shelves and drawers full of suppliers' literature. PIPE LINE CATALOG makes your buying or specifying easy, convenient, efficient and economical. Use it – and save time and money.



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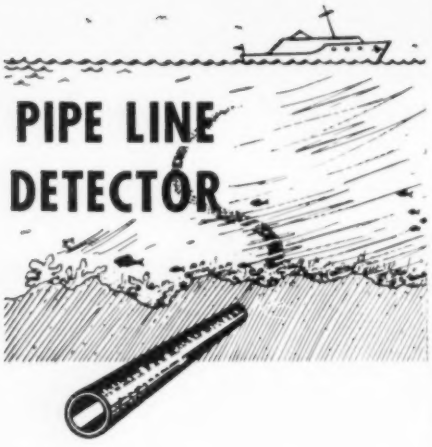

A *MARINE PIPE LINE DETECTOR* for river crossings, bays, marshes, and offshore—used to locate your pipe lines. This magnetic detector locates and determines the amount of overburden on your marine pipe—**Locates** them quickly, accurately, and economically.

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OGALLALA, NEBRASKA

New Equipment Literature

For more data on New Equipment or copies of Catalogs and Literature reviewed in this issue, use the Reader Service postcards just inside the back cover and facing the Advertisers' Index. Simply circle code numbers of items desired—sign and mail card.

Magnetic Separator

A magnetic separator for use in automatic and semi-automatic submerged arc welders has been developed by Lincoln Electric Company. It improves welding by removing flux contaminating materials accidentally picked up in handling or use.

It contains three cylindrical ainico magnets. Mill scale, pieces of steel, grinding, and other material previously picked up during use of flux are removed from flux as it passes across the magnets.

To get a copy, circle **No. E16** on Readers' Service Card, last page this issue.

Turbocharged Gas Engine

Clark Bros. Co. has issued a catalog describing its Model TPV, a 2-cycle, V-type, turbocharged gas engine designed as a compact, high horsepower driver for centrifugal pipe line compressors and liquid pumps.

Design features and operating advantages of the unit are fully described and illustrated. Models are built with 10, 12 and 16-power cylinders, rated at 4,000, 4,800 and 6,400 bhp respectively.

To get a copy, circle **No. E17** on Readers' Service Card, last page this issue.

Control Catalog

Mercoid Corporation has published a 56-page catalog listing mercury switch equipped controls for single-stage pressure, two-stage pressure, differential pressure, single-stage temperature, two-stage temperature, liquid level and mechanical movement. Transformer relays and a complete line of hermetically sealed mercury switches are also illustrated.

A dual index makes it easy to locate each control with accompanying description, specifications and engineering data.

To get a copy, circle **No. E18** on Readers' Service Card, last page this issue.

Computer Details

Computer Systems, Inc., has issued a four-page brochure describing the company's line of general and special purpose analog computers and accessories.

Included in the bulletin are details on the MC-5800 Precision Master and MC-5900 Process Master analog computers, electronic multiplier and linear programming computers. Also explained is the DYSTAC system, which incorporates the iterative capability of digital computers while maintaining speed and ease of use of analogs.

To get a copy, circle **No. E-19** on Readers' Service Card, last page this issue.

Generating Plants

D. W. Onan & Sons Inc., has published its 1960 general catalog which includes its recently added line of high-capacity electric generating plants.

The 2-color, 8-page folder lists more than 45 basic models of Onan gasoline and diesel engine-driven generator sets. A chart of representative models within each specific series outlines such details as capacity of the plant, model number, voltage, starting method, dimensions and weight.

To get a copy, circle **No. E20** on Readers' Service Card, last page this issue.

Check Valve

Daniel Orifice Fitting Company announces a catalog on its safety swing check valve available in 2-inch to 8-inch sizes. Valve comes in ASA pressure ratings of 150 and 300 pounds with standard raised-face flange facing. It has a cast, carbon steel body with stainless steel trim. Valve features a spring-loaded flapper for full seat contact and flow shut-off. Lever indicates whether valve is opened or closed.

To get a copy, circle **No. E21** on Readers' Service Card, last page this issue.

Vibration Meter

Southwestern Industrial Electronics Co. has issued a two-page bulletin describing the Model T-1A vibration meter. Included are the battery-powered T-1A's specifications and applications—measurement and analysis of gas pipe lines, machinery and installations without power outlet.

The meter is designed for accurate measurement of the velocity, displacement amplitude and acceleration of vibration.

To get a copy, circle **No. E22** on Readers' Service Card, last page this issue.

Engine Guide

"International Engines and Power Units" is a revised folder issued by International Harvester Company on its engines.

Included are 24 models, from stripped engines to complete power units. Ten are diesel, four and six-cylinder; and 14 are of four, six and V-eight-carbureted variety.

To get a copy, circle **No. E23** on Readers' Service Card, last page this issue.

Write for Bulletin

PIPELINE VENTS AND MARKERS

FLEET-LINE CO.
P. O. BOX 276-K
SHREVEPORT
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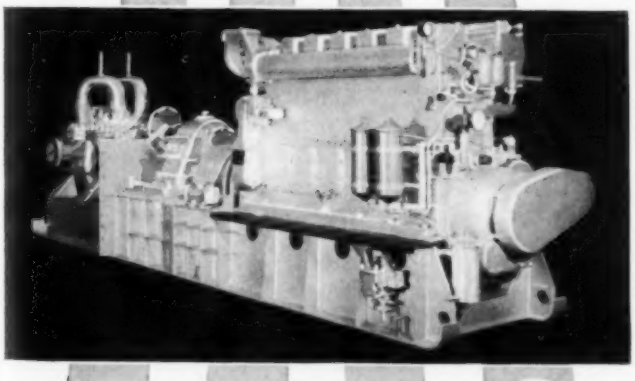
MWM DIESEL

OVER 3 THROUGH 2000 HP

ranges our production – programm comprising a suitable Diesel for every application. Even for Oil-Boring and High – Pressure Pipe-Line Pumping there are highly efficient, reliable, economic units in our catalogue.

Pipe-Line Pumping Set.

Explosion proof, consisting of four-stroke MWM-Diesel-Engine, Type TRHS 526 S, 375 HP at 1000 RPM and KSB-Pump, Type GPL-100, four-stage. Delivery: 120 m³/hr at 84 atm. gauge.



MWM DIESEL

the engine deserving of your confidence

MOTOREN-WERKE MANNHEIM AG

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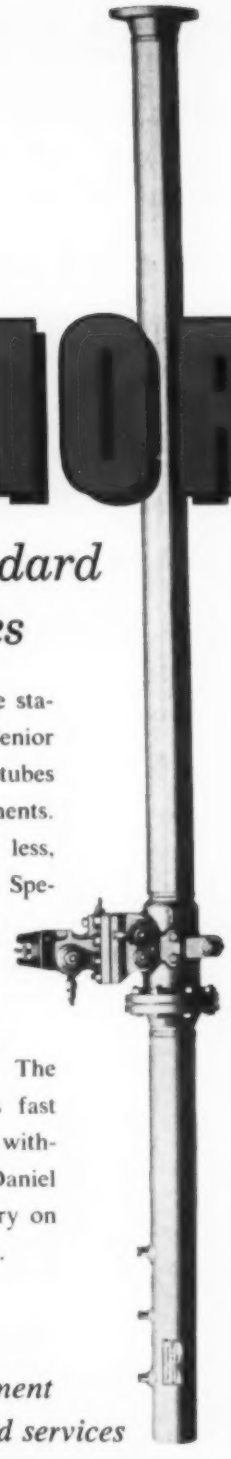
SENIOR

flangnek standard meter tubes



Used at sales and purchase stations everywhere, Daniel Senior "flangnek standard" meter tubes meet exacting service requirements. They are easy to order, cost less, and are available from stock. Special, factory-aligned upstream tubes combine with the Senior Orifice Fitting to provide a smooth approach to the orifice plate, free of offsets. The popular Senior fitting allows fast plate changing or inspection without line shut-down. See your Daniel representative for the full story on your best buy in meter tubes.

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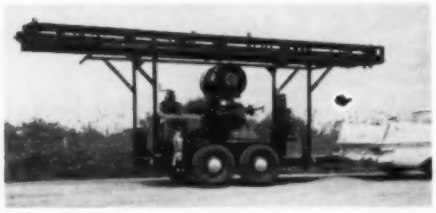
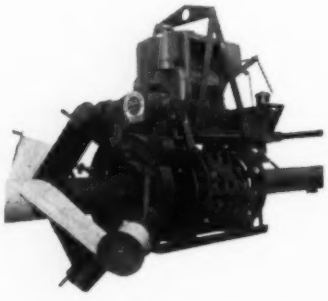


The Myoco fully portable type stationary, semi-automatic, cleaning, priming and tape wrapping machine, is quickly and easily moved from one jobsite to another by passenger automobile or pick-up. Powered with air-cooled Wisconsin motors. Sizes 2" thru 6" inclusive.



MYOCO Model OW Power Driven Cleaning and Taping machine combines two operations for increased speed of operations with less equipment. Line travel machines are available to handle pipe sizes 3" to 6", 6" to 12", and 14" to 20". A Wisconsin Model Vg4D V-type 4-cylinder heavy-duty air cooled engine, combined with the design and engineering features of this machine, guarantees uninterrupted service.

When you use MYOCO pipeline equipment, you quickly find that servicemen are experienced and available twenty-four hours a day, with fast transportation available to serve you in any way; efficient equipment operation is assured by periodical checks; and if possible, parts and supplies are shipped the same day ordered.

MORRIS-YOUNG-OWENS CO. PIPELINE EQUIPMENT AND SUPPLIES MYOCO

MORRIS-YOUNG-OWENS CO.

PIPELINE EQUIPMENT AND SUPPLIES

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PArkview 3-0110
In Canada: MYOCO LIMITED, Rural Route 1, Midland Ave. N., Agincourt, Ontario, Canada. Tel. AX 3-1211

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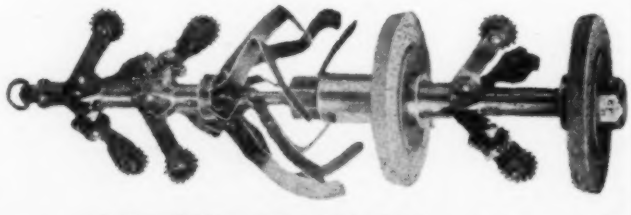
Go-Devil

NORTHRUP GO-DEVILS

Heavy Duty Model with Neoprene cup or disc drivers



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Manufacturers of **TRANSIT PIPE LINE SCRAPERS**

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Tulsa, Okla.

now . . . longer life, improved performance for pipelines, crude units . . . with Unicor

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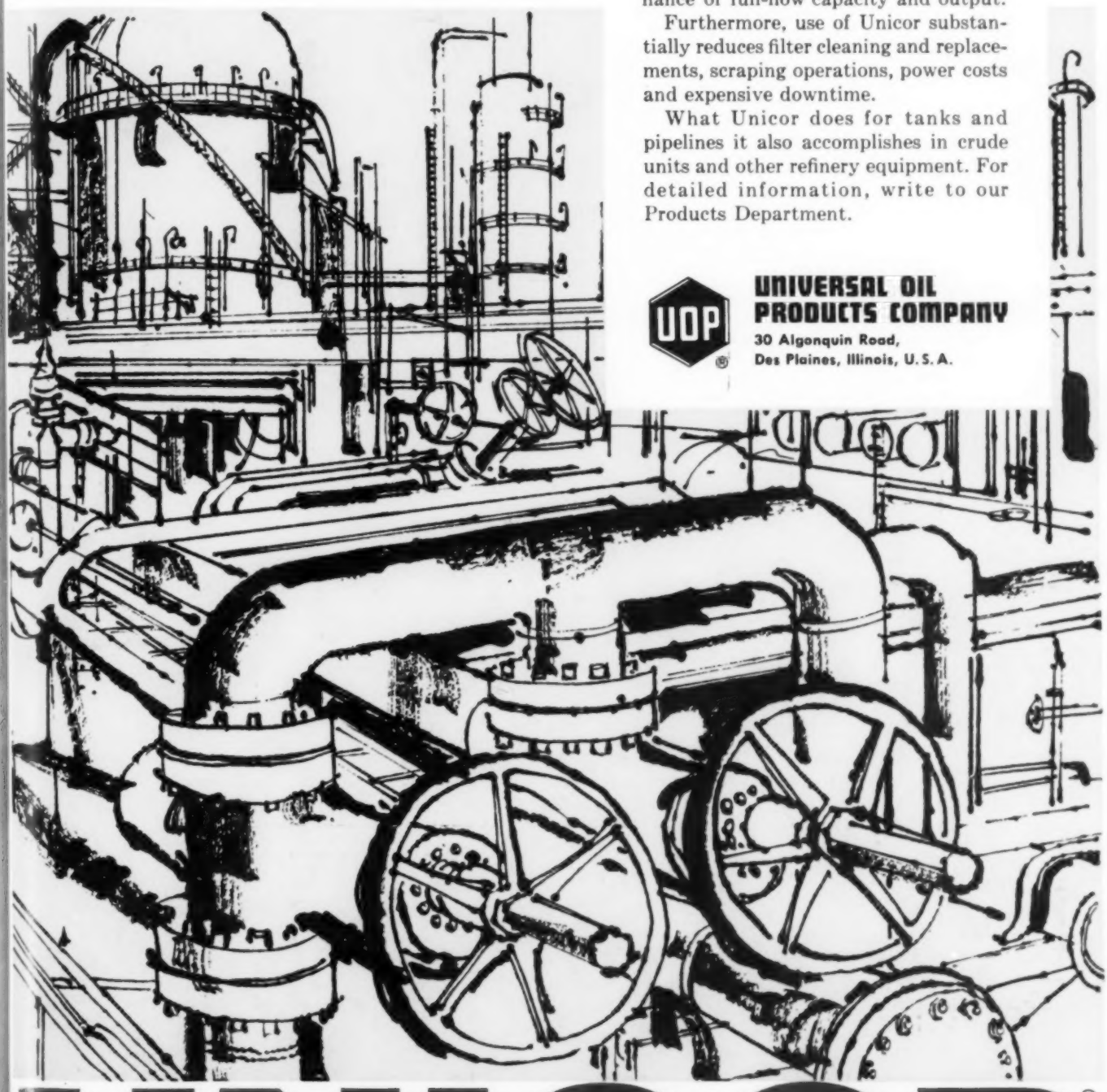
Furthermore, use of Unicor substantially reduces filter cleaning and replacements, scraping operations, power costs and expensive downtime.

What Unicor does for tanks and pipelines it also accomplishes in crude units and other refinery equipment. For detailed information, write to our Products Department.



UOP®

UNIVERSAL OIL PRODUCTS COMPANY

30 Algonquin Road,
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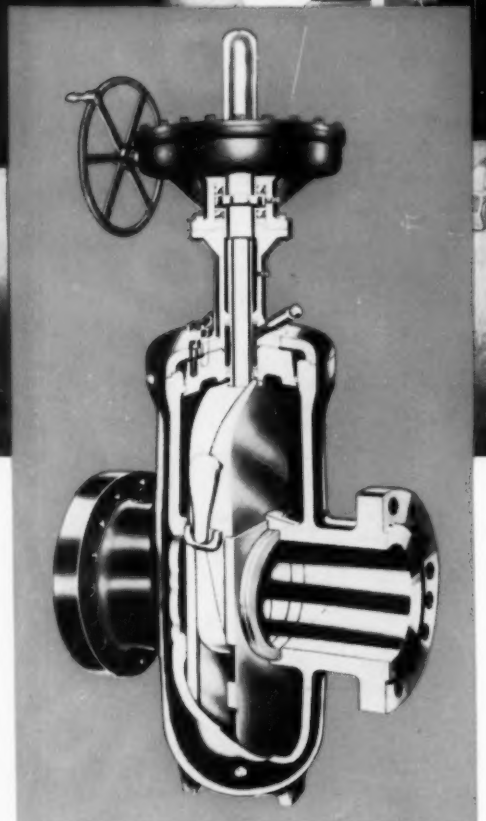
UNICOR®

"On-the-line overhaul saves time, saves money"



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These valves can be overhauled fast and easy. No other valves give you the same long-lasting service and economy. No other valves require so little maintenance, yet provide such outstanding efficiency and performance.

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